PROCEEDINGS

of the

American Society

for

Horticultural Science

1924-25

TWENTY-FIRST ANNUAL MEETING

M J DORSEY

PROCEEDINGS

OF THE

AMERICAN SOCIETY

FOR

HORTICULTURAL SCIENCE

1924

Twenty-First Annual Meeting, Washington, D.C.
December 29, 30 and 31, 1924

Published by the Society
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College Park, Maryland

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Assistant Secretary...R. D. Anthony

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CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Any person who has a baccalaureate degree and holds an official position in an agricultural college, experiment station, or Federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, and a Secretary-Treasurer, who, together with the chairman of the standing committees, shall constitute a Council to act upon all applications for membership. There shall also be an Assistant Secretary. These officers shall be elected annually by ballot.

ARTICLE VI

This Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS

SECTION 1. The President and other officers shall perform the usual duties of their respective offices. The President shall also deliver an address at each regular meeting.

SEC. 2. There shall be a Committee on Nominations consisting of five (5) members, who shall be nominated and elected by ballot at each regular meeting of the Society. It shall be the duty of this committee, at the following meeting, to suggest to the Society names for officers, referees, and members of committees for the ensuing year..

SEC. 3. There shall be an Executive Committee, consisting of three (3) members and the President and the Secretary, ex-officio. This committee shall perform the usual duties devolving upon such committee.

SEC. 4. The Committee on Nominations shall nominate referees and alternates upon special subjects of investigation or instruction, which may be referred to its consideration by the Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned them, and to report the present status of the same.

SEC. 5. There shall be a Committee on Program, consisting of three (3) members, of which the Secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society.

SEC. 6. The annual dues of the Society shall be two dollars and fifty cents.

SEC. 7. Ten members of the Society shall constitute a quorum.

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*The Constitution and By-Laws as amended from time to time.
†Since 1913 two lists of candidates have been required.

TREASURER'S REPORT FOR 1924

Voucher No.	1924	Cr.		
	Jan. 3	Stamps		$ 1.00
(1)	Jan. 3	Expenses of Secretary, C. P. Close, in attending the Cincinnati Meeting December 27–29, 1923		
		8 meals in Cincinnati	$6.15	
		2 meals enroute to Cincinnati	2.15	
		2 meals enroute from Cincinnati	2.25	
		Lodging 2 days in Cincinnati	5.50	
		8 carfares at 8c each in Cincinnati	.64	
				16.69
	Jan. 12	Stamps		2.00
(2)	Jan. 12	Dr. Harris M. Benedict, Cincinnati, Ohio. 150 dinner tickets for Cincinnati Meeting		2.00
(3)	Jan. 12	Telephone call to Telegraph Printing Co., Harrisburg, Pa., call made on Nov. 30, 1923		90
(4)	Jan. 12	Telephone call to the Telegraph Printing Co., Harrisburg, Pa.		1.90
(5)	Jan. 14	Expressage on 1923 Report manuscript to the Telegraph Printing Co., Harrisburg, Pa		.54
	Jan. 23	Stamps		1.00
	Jan. 26	Stamps		1.00
(6)	Jan. 29	Expressage on letterheads and envelopes from Geneva, N. Y		1.06
(7)	Jan. 31	The Telegraph Printing Co., Harrisburg, Pa. 450 programs for 1923 meeting		15.75
	Feb. 2	Stamps		1.00
(8)	Feb. 4	Telephone call to the Telegraph Printing Co., Harrisburg, Pa		.90
(9)	Feb. 12	W. F. Humphrey, Geneva, N. Y.		
		1990 envelopes $10.25		
		1500 letterheads 7.50		
		Postage .27		
			$18.02	
		Less trimming on oversized letterheads	.25	17.77
	Feb. 12	Joseph Hollis, Washington, D. C., trimming letterheads		.25
	Feb. 12	Stamps		1.00
	Mar. 4	Stamps		1.00
	Mar. 12	Stamps		1.00
(10)	Mar. 18	Expressage on Annual Reports from Harrisburg, Pa.		4.69
	Mar. 21	Stamps		3.00
	Mar. 24	Stamps		3.00
	Apr. 3	Stamps		1.00
	Apr. 9	Stamps		1.00
	Apr. 23	Stamps		1.00
	Apr. 26	Stamps		2.00
	May 8	Stamps		1.00
	May 13	Stamps		1.00
(11)	May 13	The Telegraph Printing Co., Harrisburg, Pa. 450 copies 1923 Report of 347 pages at $2.00 per page	$694.00	
		Excess composition on 6 point tables	40.50	
		3 inserts at $3.25 each	9.75	
		3 halftones at $3.75 each	11,25	
		Postage and mailing	46.99	$802.49

(11)	May 23	Stamps	1.00
	June 20	Stamps	6.00
	June 25	Stamps	1.00
	July 28	Stamps	1.00
	Oct. 15	Stamps	1.00
	Oct. 18	Stamps	3.00
	Oct. 20	Stamps	2.00
(12)	Oct. 20	The University Press, College Park, Md. 500 envelopes	2.50
	Oct. 28	Stamps	1.00
	Nov. 17	Stamps	1.00
	Dec. 2	Stamps	5.00
(13)	Dec. 5	W. F. Humphrey, Geneva, N. Y. 400 programs of 1924 Meeting	18.25
	Dec. 11	Stamps	1.00
(14)	Dec. 22	The Duplicating Letter Co., Washington, D. C. Mimeographing abstracts of papers for 1924 meeting	7.50
(15)	Dec. 24	The University Press, College Park, Md. Printing 150 dinner tickets for 1924 meeting	2.50
		To Balance	890.33
		Total	$1,831.02

Dr.

1924	By Balance	$648.52
Jan. 14	Purdue University, Lafayette, Ind., Report 1922	2.50
Jan. 17	J. K. Shaw, Amherst, Mass, Reports 1905, 1906, 1908 & 9, 1910	4.00
Jan. 19	W. G. Brierley, St. Paul, Minn., Report 1917	1.50
Jan. 23	Cornell University, Ithaca, N. Y. Report 1922	2.50
Jan. 28	University of Arizona, Tucson, Ariz. Reports 1916, 1917, 1918, 1919, 1920, 1921, 1922	$13.50
Feb. 6	University of Illinois, Urbana, Ill. Reports, 1918, 1919, 1920, 1921, 1922	10.50
Feb. 9	Boyce Thompson Institute for Plant Research, Inc., Yonkers, N. Y. Reports 1905, 1906, 1910, 1914, 1915, 1916, 1917, 1918, 1919, 1920, 1921, 1922, 1923	21.00
Feb. 18	Boyce Thompson Institute for Plant Research, Inc., Yonkers, N. Y. Report 1908 and 9	1.00
Mar. 3	Moore Cottrell, North Cohocton, N. Y., Reports 1920, 1921, 1922, 1923	10.00
Mar. 24	New York Agriculture Experiment Station, Geneva, N. Y., Reports 1915, 1916, 1922	5.00
Mar. 28	Brooklyn Institute of Arts and Sciences, Brooklyn, N. Y., Report 1923	2.50
Mar. 29	F. W. Faxon Co., Boston 17, Mass., Reports for 1921, 1922 and four reports for 1923	15.00
Mar. 31	His Majesty's Stationery Office, London, England, Report 1922	2.50
Apr. 1	The Marble Laboratory Inc., Canton, Pa. Report 1923	2.50
Apr. 3	Seattle Public Library, Seattle, Wash. Report 1923	2.50
Apr. 8	Leland Stanford Junior University, Stanford University, Calif. Report 1923	2.50
Apr. 9	Virginia Agricultural Experiment Station, Blacksburg, Va., Report 1923	2.50
Apr. 9	H. J. Webber, Berkeley, Calif. Reports 1905, 1906, 1908 & 9, 1910, 1912, 1913, 1914, 1915, 1916, 1917, 1918, 1919, 1920, 1921, 1922	20.50
Apr. 9	Arnold Arboretum, Jamacia Plain, Boston, Mass. Report 1923	2.50
Apr. 10	Massachusetts Horticultural Society, Boston, Mass. Report 1923	2.50

Apr	10	Thorburn and Abbott, Ottawa, Canada. Report 1923	2.50
Apr.	14	State College of Agriculture, Cornell University, Ithaca, N. Y. Report 1923	2.50
Apr.	15	University of Maine, Orono, Me. Report 1923	2.50
Apr.	18	Purdue University, Lafayette, Ind. Report 1923	2.50
Apr.	18	C. E. Stechert and Co., New York, N. Y. Report 1923	2.50
Apr.	18	Kentucky Agricultural Experiment Station, Lexington, Ky. Report 1923	2.50
Apr.	18	Prof. A. M. Sprenger, Wageningen, Holland. Report 1923	2.50
Apr.	22	Cornell University Library, Ithaca, N. Y. Report 1923	2.50
Apr.	25	Niels Esbjerg, Odense, Denmark. Report 1923	2.50
Apr.	25	University of Nebraska, Lincoln, Neb. Report 1923	2.50
Apr.	28	Agricultural and Mechanical College, Stillwater, Okla. Reports 1915, 1916, 1917, 1918, 1919, 1920, 1921, 1922, and 1923	17.00
Apr.	28	University of Minnesota, St. Paul, Minn. Report 1923	2.50
Apr.	29	Royal Veterinary and Agriculture College, Copenhagen, Denmark, Report 1923	2.50
Apr.	29	Utah Agricultural College, Logan, Utah. Report 1923	2.50
Apr.	29	Iowa State College, Ames, Iowa. Report 1923	2.50
May	3	Ontario Agricultural College, Guelph, Canada. Report 1923	2.50
May	3	Georgia Agricultural Experiment Station, Experiment, Ga. Report 1923	2.50
May	3	G. S. L. Carpenter, Hancock, Md. Report 1923	2.50
May	8	P. Stedje, Hermansverk, Norway. Report 1923	2.50
May	8	Southern Oregon Experiment Station, Talent, Ore. Report 1923	2.50
May	10	Colorado State Agricultural College, Fort Collins, Col. Report 1923	2.50
May	12	University of Wisconsin, Madison, Wis. Report for 1923	2.50
May	12	Dr. Rudolf Florin, Stockholm 50, Sweden. Report 1923	2.50
May	19	New York Botanical Garden, New York, N. Y. Reports 1921, 1922, 1923	7.50
May	19	University of Vermont, Burlington, Vt. Report 1923	2.50
May	21	Ohio Agricultural Experiment Station, Wooster, Ohio. Reports 1921, 1922 and 1923	7.50
May	27	Oregon Agricultural College, Corvallis, Ore. Report 1923	2.50
May	28	State Department of Agriculture, Harrisburg, Pa. Report 1923	2.50
May	29	Massachusetts Agricultural College, Amherst, Mass. Report 1923	2.50
June	2	University of California, Berkeley, Calif. Report 1923	2.50
June	3	Wheldon & Wesley, Ltd., London WC2, England. Reports 1922 and 1923	5.00
June	11	H. E. Whelchel, Atlanta, Ga., Report 1914	1.00
June	11	Missouri Botanical Garden, St. Louis, Mo. Report 1923	2.50
June	17	University of California, Berkeley, Calif. Report 1923	2.50
June	25	His Majesty's Stationery Office, London, England, Report 1923	2.50
July	1	Lacinio Cappelli, Bologna, Italy, Report 1923	2.50
July	9	H. B. Frost, Riverside, Calif. Report 1922	1.00
July	11	H. B. Holcombe, Marston, N. C. Report 1923	2.50
July	17	University of Missouri, Columbia, Mo. Report 1923	2.50
Aug.	5	Georgia State College of Agrculture, Athens, Ga. Report 1923	2.50
Aug.	30	John Crerar Library, Chicago, Ill. Reports 1905, 1906, 1908 & 9, 1910, 1912, 1914, 1915, 1916, 1917, 1918, 1919, 1920, 1921, 1922, 1923	23.00
Aug.	30	H. B. Tukey, Hudson, N. Y. Reports 1905, 1906, 1908 & 9, 1910, 1912, 1914, 1915, 1916, 1917, 1918	11.50
Aug.	30	State College of Washington, Pullman, Wash. Report 1923	2.50

Aug. 30	West Virginia University, Morgantown, W. Va., Report 1922, 1923	5.00
Oct. 14	The W. F. Allen Co., Salisbury, Md. Reports 1916, 1917, 1918, 1919, 1920, 1921, 1922, and 1923	16.00
Oct. 31	C. W. Atwater, New York, N. Y., Reports 1922 and 1923	5.00
Nov. 4	University of California, Berkeley, Calif. Reports 1922 and 1923	5.00
Nov. 21	F. W. Faxon Co., Boston, Mass. 2 reports for 1924	5.00
Nov. 24	Roy Larsen, Wenatchee, Washington. Report 1923	2.50
Dec. 10	Y. Asami, Tokio Imperial University, Komba, Japan. Reports for 1905, 1906, 1908 & 9, 1910, 1915, 1916, 1917, 1918, 1919, 1920, 1921, 1922 and 1923	21.00
Dec. 10	Moore-Cottrell Subscription Agencies, North Cohocton, N. Y. Report 1924	2.50
Dec. 11	Alabama Polytechnic Inst., Auburn, Ala. Report 1924	2.50
Dec. 18	F. W. Faxon Co., Boston, Mass. Reports 1922, 1923	5.00
Dec. 29	Annual Dues Collected since last meeting	820.00
	Total	$1,831.02

Respectfully submitted,
C. P. CLOSE, *Treasurer.*

The Auditing Committee reported that it had examined the accounts of the Treasurer and found them to be correct.

W. H. ALDERMAN,
W. R. LESLIE,
G. H. DARROW,
Auditing Committee.

Annual Meeting at Washington, D. C.

December 29, 30, and 31, 1924

The Washington meeting had the largest attendance from the beginning right through to the end, and the largest number of papers of any meeting thus far held. It started on time and kept right up to schedule until the time for final adjournment. Vice-President H. C. Thompson presided at the vegetable and extension sections and President Dorsey presided at all of the other sessions. Both chairmen kept things moving. With such a crowded program there was a constant feeling that "We must hurry along." Some papers were discussed, but there was not much time for discussion. That is the disadvantage of having too many papers on the program.

It was necessary to break up into sections on two half-days. On the afternoon of December 29, there was one section on vegetables with about 50 people in attendance, and one section on pomology with a larger attendance. On the morning of December 30, the extension session had an audience of 30 and the general session an audience of perhaps 60. At the joint session with Section O, Agriculture, the college courses in horticulture and the measuring of experimental results were the topics discussed by our speakers. The two speakers from Section O discussed commercial fertilizers and green manure crops. There were about 100 members present and they divided their time between our meetings and those of the various biological societies. Ninety-eight members and friends attended the society dinner on the evening of December 30.

President Dorsey held the speakers strictly to their time limit giving each one a warning signal two minutes before his time was up. Some of the papers of absent authors were read by a member from the same institution, the others were read by title only. We are faced with the puzzling problem of handling all of the papers offered for the program. The eighty papers on this program were more than enough for a three days' meeting.

The 1925 annual meeting will be held in Kansas City, Missouri.

Effect of Debudding in the Formation of Scaffold Branches upon Leaf Surface and Terminal Growth

By F. N. FAGAN, *Pennsylvania State College, State College, Pa.*

AT OUR Society meeting in 1923 the writer presented a short paper entitled "Selecting Buds for the Development of Frame Work Branches of Apple Trees." The work reported on at that time looked encouraging and in the spring of 1924 we decided to try debudding upon pear, sweet cherry, sour cherry, European plum, peach and duplicate the work again on the apple.

One hundred June buds of Belle peach, 10 trees each of one year whips of Kieffer pear, Black Tartarian cherry, Montmorency cherry, Bradshaw plum and Stayman Winesap apple, were selected, making a total of 150. These were planted as early in the spring of 1924 as possible and one-half of each kind were debudded and one-half pruned to a whip as in common practice.

In removing buds an effort was made to select for retaining as the base of branches those which were well distributed over the young trunks. The top of the whips above the highest selected bud was then pruned off. In pruning the control trees the common practice of heading back to a whip was followed.

On August 9, 1924, all leaves on the 150 trees were counted and leaf measurements taken.

After all leaves had fallen from the trees and the dormant season well advanced, the length growth of all terminals (this includes side branches but not sub-laterals) on the trees, was taken.

Tables 1 and 2 give the range in number of leaves and the average number of each lot under date of August 9, 1924, and the range in branch growth and the average branch growth of each lot for one full growing season.

TABLE I

Total Number and Average Number of Leaves per Tree on Pruned and Debudded Fruit Trees of Different Kinds

Kind of Tree	Pruned or Debudded	Number of Trees	Leaves per Tree		Average Leaves per Tree
			Lowest	Highest	
Peach	Pruned	24	73	226	142.5
Peach	Debudded	23	87	247	178.2
Plum	Pruned	5	188	261	222.2
Plum	Debudded	5	163	270	204.4
Apple	Pruned	5	129	166	150.6
Apple	Debudded	5	72	134	112.0
Sour Cherry	Pruned	5	140	206	159.2
Sour Cherry	Debudded	5	150	194	170.8
Sweet Cherry	Pruned	5	115	191	147.8
Sweet Cherry	Debudded	5	115	146	134.4
Pear	Pruned	5	102	145	128.0
Pear	Debudded	5	103	156	138.2

The average number of leaves on all pruned trees was 158.3, and the average number for all debudded trees was 156.3.

TABLE II

Total Terminal Growth of Five Trees of Each Kind, Average Terminal Growth per Tree and Average Growth of Each Branch on Pruned and Debudded Trees

Kind of Fruit	Number of Trees	Total Terminal Growth, inches	Average Terminal Growth per Tree, inches	Average Growth of Each Branch, inches	Pruned or Debudded
Plum	5	637.0	145.4	18.7	Pruned
Plum	5	562.5	112.5	21.6	Debudded
Sour Cherry	5	628.0	125.6	19.03	Pruned
Sour Cherry	5	674.5	134.9	18.2	Debudded
Sweet Cherry	5	386.0	77.2	15.4	Pruned
Sweet Cherry	5	362.0	72.4	15.7	Debudded
Pear	5	434.0	86.8	18.8	Pruned
Pear	5	488.0	97.6	18.7	Debudded
Apple	5	478.5	95.7	14.9	Pruned
Apple	5	397.5	79.5	16.5	Debudded

From a study of these tables the writer draws the following conclusions:—(1) Debudding, instead of pruning, does not reduce the number of leaves to any appreciable extent. (2) Debudding does not reduce the total terminal branch length to any appreciable extent. (3) Debudding aids in selecting branches upon the trunk of a one year whip in such a way as to avoid bad crotches in future years. (4) Debudding aids in spreading the scaffold branches in a more uniform manner upon the trunk with spacing as the grower may desire.

At this date, December 29, 1924, we have not completed the compiling of the leaf surface from the measurements, or completed the measurements of the terminal branch growth of the peaches under test.

Plate I shows a debudded one year apple whip during the first growing season.

PLATE I. A debudded one year whip apple during the first growing season. Picture taken from farm of Mr. P. R. Kraybill, Rheems, Pennsylvania.

The Rate of Growth and the System of Branch Formation Developed by Peach Trees in the Nursery and the Effect of Summer Pruning Upon Same

By M. A. Blake, *University of New Jersey, New Brunswick, N. J.*

THE BRANCHING system or pattern of a one-year-old nursery peach tree is a matter of some practical importance to the peach grower at the time of planting the tree in the orchard. Nursery trees of the medium grades from three to five feet in height are at planting time commonly pruned free from branches and cut back to a height varying from six to twenty-four inches according to the ideal of the grower. When a tree is cut back to a height of 18 inches the grower desires the tree to form branches immediately below that point with the result that the tree will have a short trunk about eight to 12 inches long extending from the surface of the soil to the lowest branch.

Experiments at the New Jersey Station* show that there is a marked difference in growth made by peach trees when cut back to different heights when set. In general, trees cut back to a height of 18 inches made the poorest growth of any the first season after planting and not infrequently died back for about six inches. This led to the observation that when nursery peach trees are cut back to a point on the trunk just above where there are several well developed buds, the trees readily form a head and start into growth. On the other hand when a nursery tree is cut back to a point just above a series of well developed side branches there are but few, if any, well developed buds upon the trunk and an irregular head at that point may be the result, and the tip or stub frequently dies back a few inches to a point where there are well developed buds.

Peach trees as they come from the nursery vary in their branch system or pattern. Very small trees under three feet in height have but few branches. Larger trees may present a fairly even distribution of branches from the point of budding to the tip while others may have a distinctly irregular system. Series of branches alternate with spaces of trunk where there are no branches. These observations suggested the inquiry as to what factors are responsible for the system of branching which in nursery tree develops.

Rate of Growth of Nursery Trees

During the years 1922, 1923, and 1924, a close study was, therefore, made of the growth of peach trees the season following budding. The variety observed was Elberta in 1922 and 1923, and Wilma in 1924. The latter variety very closely resembles Elberta in habit of growth. The season of 1922 was very favorable for growth early in the season. That of 1923 was characterized by a marked drought beginning early in August, while 1924 was about 10 to 14 days

*N. J. Agr. Exp. Sta. Bul. 293.

later than normal, but provided most exceptional growing conditions. Never before at this station have trees been observed to continue growth until October 1.

The outstanding feature of the growth of the trees for the three years is the fact that such a large percentage of their growth is made early in the season. Thirty-four to 36 per cent of the total growth in height was made by June 1 in 1922 and 1923, 57 to 62 per cent by June 15, and 76 to 80 per cent by July 1. The entire growth of the trees was completed soon after August 1 in both years. In the late season of 1924, the trees attained 60 per cent of their growth by July 15 and 86 per cent cent by August 1. They continued growing slowly until September 27.

Rate of Growth Per Day

During 1922, the trees attained an average growth of 1.37 inches per day from May 21 to 27 and 1.08 inches per day from June 3 to 12. In 1923, the highest rate of growth was .99 inch per day from May 29 to June 6, and in 1924 .90 of an inch per day from June 17 to 25.

The fact that peach trees in the nursery make such a rapid growth and attain such a large proportion of their height early in the season has practical significance. For example, the trees actually make considerable growth before the Oriental peach moth is likely to check them.

Trees Which Start Early Make the Most Growth

It was observed that where the inserted bud upon the seedling stock started into growth promptly the trees made a good growth. On the other hand, if for any reason the bud failed to start quickly because of a poor union with the stock, or for any other cause, the tree was soon far behind the others. Slow starting buds even upon large seedling roots are often exceeded in growth by quick starting buds upon much smaller seedlings.

The trees in the nursery row which start growth first have the advantage of all the light, moisture and plant food which is available, and since the trees are ordinarily only a few inches apart competition is keen and laggards are soon hopelessly behind. Buds that do not become well attached to the stock through faulty technique in budding and tying, are likely to be slow in starting growth the next spring. Nurserymen, therefore, can well afford to give close supervision to their budding and tying gangs.

Some Established Facts in Regard to Branch Development upon Trees

The arrangement of the leaves on the stem of any plant is termed phyllotaxy. Where only one leaf occurs at a node the phyllotaxy is alternate and if a line be drawn connecting one leaf base with another it will pass spirally around the stem until a leaf is reached whose base is directly over the one selected as a starting point.

The phyllotaxy of the peach is of this type or alternate. The leaf buds which later develop into branches are formed in the axils of the leaves so the branch system or pattern is alternate. Whether a branch develops at each bud or node depends upon several factors including available light and the vigor of the tree.

A tree attempts to form a branch and leaf mosaic which will permit it to take full advantage of the light available. A plant standing by itself with no competition from other plants or things will, therefore, tend to form a well balanced head with branches extending in all directions. On the other hand, if the light is nearly or entirely shut off from one side by another plant, or an obstruction, such as a building or wall, few if any branches will form on that side. The branch pattern which a tree finally assumes will therefore be influenced to a marked degree by the light environment in which it develops.

The Growth Habit of the Nursery Tree

A peach tree in the nursery develops from a single bud and normally forms a central stem or leader with a certain number of radiating branches. The trees ordinarily stand a few inches apart in the row, but there is considerable variation in distance in different parts of the same row and between trees in different rows. There is competition between the trees for light as well as for moisture and plant food, and it varies in degree in different parts of the nursery.

The Relation of Vigor to Branch Formation

Under similar light conditions peach trees of the smaller and lighter grades have fewer and less vigorous branches than trees which develop to a caliper of three-fourths inch or above. This is to be expected since the development of branches along the stem of a plant is the direct result of elaborated plant food being directed to those points. The fact that there are several rapidly growing branches near any given point on the stem definately indicates that at the time it is a region of relatively high vegetative activity. If just above this cluster of branches there is a section of stem free from branches it indicates a region of less marked vegetative development.

The Relation of the Rate of Elongation of the Main Stem to the Branch Pattern

It might be inferred at first thought that nursery trees with a variable branch pattern are the direct result of fluctuations in the rate of elongation of the main stem and that as soon as a few branches begin to develop at any one point the growth of the main stem just beyond them is slowed down because of the diversion of plant food to those branches. Measurements of the growth of the trees, however, do not entirely sustain such a theory. The main stems of two trees may be elongating at the same rate and one form side branches during that period, and the other not. Under exactly

similar light and growing conditions the rate of elongation of the main stem might be an accurate measure of general vigor, but otherwise it may be misleading. A stem or shoot may elongate very rapidly in reduced light, but another extending at the same rate in full sunlight may develop much more substance and be more vigorous.

Rate of Elongation of the Stem is a General Indication of Vigor

Although the rate of elongation of the main stem of a tree is not a certain measure of comparative vigor it serves in a general sense. In the same nursery the smaller and weaker trees grow more slowly than the larger trees and there is a relation between height and vigor where light conditions are similar. Ordinarily a one-year-old nursery peach tree five feet in height will caliper three-fourths inch or more, but it may not if developed under reduced light conditions.

Observations at New Brunswick

During the season of 1924, Wilma trees at New Brunswick did not develop any side branches when the rate of growth of the main stem was reduced to .20 inch per day. Only an occasional branch was formed when the growth was reduced from .24 to .36 of an inch per day. All branches which formed were on growth which took place several weeks earlier. In general, the greatest number of side branches was formed when the trees were exceeding a growth of .80 of an inch per day.

During May and June when the trees were growing very rapidly in height, the portion of the stem which grew one week developed side shoots the next if any were developed at all. Any buds which did not develop into shoots the second week after that portion of the main stem had been formed remained dormant to the end of the season with a few exceptions Late in the season when growth was stimulated by the very exceptional growing conditions which prevailed in 1924 at New Brunswick, a few side buds near the tips of the trees pushed out into short shoots.

Trunks Free of Branches From About 15.5 to 23.5 Inches Above the Bud

During 1924, the check or untreated Wilma trees developed buds but not branches on the main trunk from about 15.5 to 23.5 inches above the bud. Such trees if pruned to any height from 20 to 25 inches when transplanted to an orchard site would be certain to put forth an adequate number of shoots to form a well balanced head. Such a branch pattern does not occur every season or upon all trees the same season. What is the reason?

Test of the Removal of Side Shoots upon the Branch Pattern

In order to ascertain the factors influencing the branch pattern of nursery peach trees in 1923 and 1924, some studies of the effect of the removal of side shoots were made.

Duplicate sets of nursery trees were selected at the beginning of the season and subjected to the following treatments.

No. 1.	No side shoots removed.	
" 2.	Side shoots removed to height of	12 inches.
" 3	" " " " " "	18 "
" 4	" " " " " "	24 "
" 5	" " " " " "	40 "
" 6	All side shoots removed.	

When a side shoot on the main stem of a tree had attained an inch in length it was recorded as forming at that period. Any side shoots that were to be removed were pinched off when they had attained this length or a bit more.

Most of the trees had formed shoots to a height of 12 inches by June 4 and the pruning outlined in Treatment No. 2 was completed on most of the trees at that time. By June 17 the trees had produced side shoots so that Treatment No. 3, "Shoots removed to 18 inches", could be completed and Treatment No. 4, "Removed to 24 inches", was completed on some trees at the same time.

Removal of Side Shoots Modifies Branch Pattern

Trees of medium to good vigor started forming side branches at a height of about five to six inches above the point of budding and usually developed from five to eight branches on the trunk within the five to 15 inch zone. The check trees then developed dormant buds only in the zone from about 15 inches to 23 inches above "the bud." The trees in treatment No. 2, however, from which the shoots were removed to a height of 12 inches, formed branches in that zone, and continued to develop them to a height of about 26 inches where a tendency was noted to form buds only for several nodes. The trees from which the shoots were removed to a height of 18 and 24 inches, respectively, also formed shoots in the 15 to 23 inch zone, but these were removed according to the plan. All trees formed branches freely immediately beyond the point where the removal of shoots stopped. The trees in treatment No. 6, from which all shoots were removed as soon as they formed, continued to push out shoots at each consecutive node upon the stem until late August and early September when the rate of growth had been reduced to about one-third of an inch per day. The side shoot removal tests clearly showed how one can change the branch pattern of a nursery tree and also furnished evidence as to the factors influencing branch formation.

Effect of Shoot Removal upon the Elongation of the Main Stem

The removal of the side shoots to heights of 12 and 18 inches respectively did not noticeably increase the rate of growth of the stem. Removal of the side shoots to a height of 24 inches slightly increased the rate of growth from June 25 to July 12. Removal of shoots to 40 inches increased the rate of growth from June 25 to July 26, and the removal of all the shoots increased the rate of growth from June 25 to September 27, or to the very end of the season.

Appearance of Trees from Which All Shoots were Removed

The trees from which all side shoots were removed as they developed make a striking appearance in the nursery row. The leaves at the nodes developed to a very large size and were dark green in color. One tree attained the height of 89 inches in 1924. In 1923, Elberta trees in a similar treatment continued to grow longer during a drought than unpruned trees and maintained a better color.

Effect of High Budding Upon Branching Pattern

During 1922 and 1923, some peach stocks were budded 12 inches above the surface of the soil instead of the usual two to four inches. The majority of the trees developed unusually vigorous side branches just above the point of budding which was succeeded by a zone in which few or not any branches were formed. The only exceptions to the rule were trees standing several feet away from all others, and, therefore, receiving the full benefit of the available light. Such trees formed branches at nearly every node

The reason that trees budded high tend to develop vigorous side branches immediately above the point of budding, is that translocation of food downward is slightly inhibited by the exceptionally long section of seedling stock which is allowed to remain and branch formation at the point of budding is thus stimulated.

Branch Pattern a Matter of Vigor, Light and Food Distribution

Three years' observations of the growth of peach trees in the nursery indicate that the branch pattern which a tree develops is largely a matter of vigor, light and food distribution. Trees decidedly lacking in vigor produce relatively few branches. Vigorous trees tend to form a fairly regular branching pattern when exposed to full sunlight from all sides. Under nursery conditions in the East, however, there is likely to be considerable competition for light between the trees in the nursery row. When one or several side shoots form on the trunk and grow vigorously they tend to shade the portion of the trunk immediately above them and if dull days occur during the same period the tree is not likely to push out more shoots to add to the competition. In other words, the branching pattern under such conditions becomes largely a matter of light. A bud which is formed in a position on the trunk or branch which receives an abundance of light, develops into a shoot apparently as a result of the distribution of elaborated food to that point. Buds which are shaded to any considerable degree do not receive food to stimulate their development unless the portions of the tree or branches above or beyond are checked and prevented from making their normal growth.

The peach nursery in 1924 was located on the northwest side of a woodland and did not receive the direct rays of the sun early in the morning and from June 11 to 21 there was only one clear day. The reduced light to which the trees were exposed during that time appears to account for the 15 to 23 inch zone, which was generally free of branches, on the trunks of many trees.

A Practical Application

If one desires to have well formed buds upon the trunks of nursery trees at a height of from 12 to 20 inches instead of branches, it can likely be accomplished by shading the trees from the side for about a week, immediately after they have attained a height of about 18 inches. The shade should not be maintained much longer as it would tend to inhibit sturdiness and vigor.

Trees from Which All Side Shoots were Removed Developed Long Tap Roots in 1923

Another feature which developed as a result of the studies of the factors influencing branch pattern of nursery peach trees in 1923, was that the trees from which all side shoots were removed had exceptionally long tap roots. Whether this was due directly to the effect of the pruning or some other factor is still a question. The 1924 tests, however, are located upon a different soil area from those of 1923, the treatments are carefully duplicated and when the roots are examined the necessary proof may be at hand.

Correlation Studies in Peach Tree Response

By H. L. Crane, *West Virginia University, Morgantown, W. Va.*

THE YIELD of apples has been shown to be closely correlated with the increase in trunk circumference by Waring of Pennsylvania and others. Trunk circumference records have been shown to have a decided value which may approach that of yield as an aid in the correct interpretation of apple orchard field experiments. In analyzing the data in West Virginia Agricultural Experiment Station Bulletin No. 183, entitled "Experiments in Fertilizing Peach Trees," indications were found which seemed to show that the increase in trunk circumference was not as good an index of the vegetative condition or of the fruitfulness of peach trees as it has been found to be with apple trees.

In all field experiments the records taken are subject to error which may be great or small depending on the nature of the character being studied, and the environmental factors other than the treatment given which may affect it. It is also true that the greater the extremes in environmental conditions or the easier the character or nature of the plant is changed by such extremes, the greater the error. The peach crop, the writer believes, is much more uncertain and more easily influenced favorably or otherwise than the apple crop. Peach buds are more tender and more easily killed by freezing. Again brown rot may exact its toll, as well as conditions brought about by curculio and borers may reduce the yield.

To know what data will best measure the response of peach trees to some particular treatment is often a problem. Growth and yield may be closely associated as in the apple, yet the treatment given

may promote growth at the expense of yield as reported in the West Virginia experiments where cover crops of soy beans and crimson clover were used. On the other hand, the treatment given may promote fruitfulness at the expense of growth as Chandler has shown in the case of the apple, where heavy production has reduced the vegetative condition of the tree. There is still another condition, a given treatment may promote growth and fruitfulness yet the condition of the tree be such that it is unable to withstand adverse environmental conditions and then either growth or yield or both are reduced. A good example of this is the results of late applications (July 15) of nitrate of soda to peaches which caused vigorous shoot growth, large gains in trunk circumference and setting of a large percentage of fruit buds. Yet, yield was reduced as the weather of most winters was of such a nature as to kill the larger part of the fruit buds. With questions such as these in mind the writer has attempted to find out the relation which exists in the peach between growth and yield.

The material used for this study was taken from the data secured in a study of the response of peach trees to nitrogen. The orchard was located in Morgan County at Cherry Run. The trees were planted in 1911 and in the spring of 1915 the fertilizer experiments were started. The experiment as outlined consisted of 24 plots of 25 trees each. To avoid cross feeding, plots five trees square were used, while records were taken only on the nine interior trees, the remaining 16 formed a guard row around each plot. Only one variety, Elberta, was used. Nitrate of soda from two to six pounds per tree was applied each year to the trees receiving nitrogen. Nine of the 24 plots did not receive nitrogen, but did receive phosphorus, potassium, or cover crops, or combinations of these, or nothing. All the orchard received clean cultivation and a cover crop, which was usually rye, was seeded each year. Records were taken for the six year period 1915 to 1920 inclusive.

The coefficient of correlation was calculated between the characters total increase in trunk circumference, and the total average shoot growth, regardless of fertilizer treatment. This was found to be $.53 \pm .039$ which according to all standards is a significant correlation.

The coefficient is not as high as would be expected since both characters are a measure of growth. It is obvious then that shoot growth is not as closely correlated with gain in trunk girth in the peach as has been thought or more probably the method of arriving at the average length of shoot growth was greatly in error. The latter is substantiated by the coefficients of variability. The ceofficient of variability for shoot growth being $14.49 \pm .54$ and for increase in trunk circumference $22.29 \pm .84$, hence it would seem that in taking the measurements of shoot growth the observers unconsciously selected the longer and more uniform terminals.

Yield and increase in trunk circumference are correlated, the coefficient of correlation in this case being $.383 \pm .045$, which is significant. In determining the coefficient of correlations all records were used regardless of fertilizer treatment. Apparently yield and

the increase in trunk circumference are not as closely correlated in the peach as one would suppose from the correlation coefficients which have been determined for the same characters for the apple, or some factor or factors were operating to lower the correlation.

The records used are for the second to seventh crops inclusive and while they were yet young. Thus it would not seem possible that the small coefficient of correlation was due to old age as has been suggested in the case of apple trees.

To determine the influence of nitrogen on the coefficient of correlation, the tree records were divided into two classes, those which received nitrogen and those which did not. The basis for this grouping was that all trees receiving nitrogen either in the form of nitrate of soda or manure, regardless of amounts, are included in the nitrogen group, while all those which received phosphorus, potassium, legume cover crops, or nothing, singly or in combinations, were placed in the no nitrogen group. The coefficient of correlation for the total yield and increase in trunk circumference of those trees which did not receive nitrogen was .419 ±.068, a slightly higher coefficient than was secured when all the records were grouped together, yet not sufficiently large to make any difference. The correlation coefficient of the same characters for those trees which received nitorgen was .403 ±.058, which is only .016 smaller than for those trees which did not receive nitrogen. In both cases however, the coefficients are higher than when the records were grouped together regardless of fertilizer treatment. It then is evident that the frequency distribution has been such as to lower the correlation when all the records were grouped together. From these data it would seem that nitrogen has not affected the coefficient of correlation. It will be shown later, however, that nitrogen has a decided effect in reducing the correlation. With both yield and increase in trunk circumference the coefficients of variability are higher in the case of those trees which did not receive nitrogen than with those which did.

Total yield and shoot growth are equally as well correlated as is yield and increase in trunk circumference. In the case of the former the coefficient of correlation was found to be .376 ±.046 while with the latter .383 ± .045, when all trees are considered. But of the two characters length of shoot growth and increase in trunk circumference, length of shoot growth is the least variable as its coefficient of variability was only 14.49 ± .54 as compared with 22.29 ± .87 for the increase in trunk circumference. Hence, it would seem that length of shoot growth and increase in trunk circumference are equally as good measures of the yielding capacity of peach trees.

As the crop produced in any one year is borne on wood produced the previous season, the coefficient of correlation was calculated between shoot growth of 1919 and the yield of 1920, which was the heaviest crop year. This coefficient was found to be .286 ± .049 which is not significant and is considerably smaller than when the data for the whole six year period were used. The correlation between the growth produced in 1920 and the yield of 1920 was found to be .276 ± .049. These coefficients of correlation taken with that for

the yield of 1920 and the increase in trunk circumference made in 1919, would seem to indicate that factors other than growth were dominant in influencing the yield.

To determine what influence nitrogen has on the correlation between shoot growth and yield, coefficients of correlation were calculated for total shoot growth and total yield for those trees which did not receive nitrogen and for those which did. In the former case the coefficient of correlation was .433 ± .067, and in the latter .303 ± .063. The data show that the correlation between shoot growth and yield is much higher without nitrogen than with it.

The coefficients of variability are likewise higher without nitrogen than with it. It will be recalled that the same thing was true of the coefficients of variability determined for yield and increase in trunk circumference. In every case these coefficients substantiate those determined by Waring and show that nitrogen is a factor in reducing the degree of correlation between growth and yield.

In order to see further the effects of nitrogen in reducing the correlation between growth and yield, the records were separated according to the fertilizer treatment into six groups. These groups were (1) the check trees which received nothing; (2) all the trees which received phosphorous or potassium, regardless of combination, including the check trees, as well as those which received a legume cover crop; (3) all trees receiving nitrogen regardless of the amount; (4) all trees receiving two pounds of nitrate of soda each year; (5) all trees receiving four pounds of nitrate of soda; (6) all trees receiving six pounds of nitrate of soda. In the last three groups some of the trees received phosphorus or potassium, or both, in addition to the nitrogen. In each group the number of inches gained in trunk circumference by the individual trees during the six year period were added together, the average length of the terminal shoot growth, and likewise the number of pounds of fruit produced. Then the summation of the pounds of fruit produced by each group was divided by the summation of the inches gained in trunk circumference. The quotient was taken as the pounds of fruit produced per inch increase in trunk circumference. In the same manner the pounds of fruit produced per inch of terminal shoot growth was calculated. The results of these calculations are given in Table II.

From this table it will be seen that the check trees produced 3.678 pounds of fruit per inch shoot growth, and 53.985 pounds for each inch gain in trunk circumference. The group of trees receiving no nitrogen yielded .543 pounds per inch of shoot growth and 7.997 pounds per inch gain in trunk circumference less than the check trees. This difference may be accounted for by the small yield of those trees receiving legume covers (soy beans or crimson clover) or of those to which potassium was applied. The results for all of the trees receiving nitrogen show clearly the effects of this element of fertility in reducing the degree of correlation. The trees to which nitrogen was applied yielded 1.006 pounds per inch of shoot growth and 11.62 pounds per inch increase in trunk circumference more than the non-nitrogen trees. From these data it may be seen that nitrogen

TABLE I

Coefficients of Correlation Between Gain in Trunk Circumference, Average Length of Terminal Shoot Growth, and Yield in Pounds of fruit Produced, Together with Coefficients of Variability for Circumference Shoot Growth and Yield.

Characters Correlated	Number of trees	Coefficient of correlation	Coefficients of Variability	
			Shoot Growth	Circumference
Total shoot growth and total increase in trunk circumference	161	.53±.039	14.49± .54	22.29± .84
			Yield	Circumference
Total yield and total increase in trunk circumference	161	.383±.045	30.33±1.14	22.29± .84
Yield 1920 and increase in trunk circumference 1919	161	.253±.050	45.34±1.70	47.82±1.79
Total yield and total increase in trunk circumference, no nitrogen	54	.419±.068	34.87±2.03	28.40±1.65
Total yield and total increase in trunk circumference, nitrogen	107	.403±.058	25.21±1.24	22.26±1.09
			Yield	Shoot growth
Total yield and total shoot growth	161	.376±.046	30.33±1.14	14.49± .54
Yield 1920 and shoot growth 1919	161	.286±.049	45.34±1.70	25.51± .95
Yield 1920 and shoot growth 1920	161	.276±.049	52.33±1.96	27.60±1.03
Total yield and total shoot growth, no nitrogen	54	.433±.067	34.87±2.03	15.40± .89
Total yield and total shoot growth, nitrogen	107	.303±.063	25.21±1.24	13.68± .67

Table II

Showing Total Length of Shoot Growth in Inches, Inches Gain in Trunk Circumference, and yield in Pounds of Fruit, Together with Their Average in Pounds of Fruit Produced per Inch of Shoot Growth and Increase in Trunk Circumference for the Six Year Period 1915 to 1920 Inclusive.

Group	Treatment	Number of trees	Total shoot growth, inches	Total gain in trunk circumference, inches	Total yield of fruit buds	Pounds of fruit per inch of shoot growth	Pounds of fruit per inch gain in trunk circumference
1	Check	22	2797.82	190.64	10291.74	3.678	53.985
2	All—no nitrogen	54	7207.22	495.78	22799.97	3.135	45.988
3	All—nitrogen	107	15321.50	1103.32	63449.75	4.141	57.508
4	2 pounds $NaNo_3$	17	2149.30	150.36	8428.09	3.921	56.052
5	4 pounds $NaNo_3$	56	8237.80	598.29	31742.22	3.853	53.054
6	6 pounds $NaNo_3$	21	2926.70	200.40	14217.87	4.858	70.947
*	4 pounds $NaNo_3$	43	6379.40	456.93	26014.21	4.077	56.932

*Same group as 5 only that the records of 13 trees, four of one plot and nine of another, (all remaing trees in these plots), were eliminated because of conditions which were plainly not the result of the fertilizer treatment The trees of the first plot were badly injured by borers and those of the second plot which received an application of four pounds of nitrate of soda July 15 had such a large percentage of the buds killed during the winters that their yield was greatly reduced.

Table III

Effect of Nitrogen Applications in Varying Amounts on the Length of the Terminal Shoot Growth, Gain in Trunk Circumference and Total Yield for a Six Year Period.

Treatment	Number of trees	Average length of shoot growth in inches	Average gain in trunk circumference in inches	Average per cent of fruit buds set.[1]	Average total yield in pounds
All trees receiving no nitrogen	54	13.346	9.18	64.6	422.22
Two pounds nitrate of soda per tree	17	12.643	8.84	65.5	495.77
Four pounds nitrate of soda per tree	56	16.496	10.68	62.2	566.82
Six pounds nitrate of soda per tree	21	13.936	9.54	66.7	677.04

[1]Set of buds estimated each year.

has increased the average length of the terminal shoots, and the circumference of the trees, but that the yield has been increased beyond all proportions of tree growth.

The plan of the experiment offered still another point of attack as various trees received two, four, and six pounds of nitrate of soda. From table II, it will be seen that a two pound application of nitrate of soda increased the yield of fruit per unit of shoot growth, or trunk circumference, over that of the no nitrogen trees by approximately 25 per cent. When four pounds of nitrate of soda were applied the yield of fruit was reduced per unit of growth as compared to those receiving the two pound application. The data become confusing when the records of the trees receiving six pounds are considered, for they yielded considerably more fruit per unit of growth than did those receiving two pounds. In other words, a two pound application increased the yield of fruit per unit of wood growth roughly 25 per cent as compared to those trees receiving no nitrogen. A four pound application increased the yield only about 20 per cent. While a six pound application caused the trees to produce approximately 25 per cent more than the trees receiving two pounds or about 50 per cent more than the tree receiving no nitrogen. There is, nevertheless, one prominent feature that stands out, that is the great influence of nitrogen in reducing the correlation between growth and yield. The increase in yield in pounds of fruit for the two and six pound nitrate application over that of the trees not receiving nitrogen being .786 and 1.723 pounds per inch shoot growth, and for the trunk circumference 10.064 pounds and 24.959 pounds respectively. This accounts in a measure for the low coefficients of correlation between growth and yield.

Why did those trees which received four pounds of nitrate of soda yield less per unit of growth than did those trees receiving two pounds is a question that immediately comes to mind. This is especially true when it is also considered that those trees receiving six pounds of nitrate yielded so much more per unit of growth than did those receiving only the two pound application.

In the first place, there is included in the 56 trees receiving four pounds of nitrate, 13 trees, all of two plots, which have yielded less than the checks. This has been due to conditions other than the effect of nitrate, one plot was badly damaged by borers while the other received the nitrate of soda application July 15, with the result that such a large percentage of the buds was killed during the winters that their yield was greatly reduced. When these trees are eliminated, the yield per unit of growth is slightly greater than that of the trees receiving the two pound applications. The difference in yield, however, is not significant.

In Table III are shown the effects of nitrogen in varying amounts on length of terminal shoot growth, increase in trunk circumference and total yield for the six year period. The yield of fruit has been on the average in proportion to the amount of nitrogen applied to the trees, that is, with the addition of each two pounds of nitrate of soda there has been a corresponding increase in yield. The growth of the trees

did not respond in the same way. The trees receiving a two pound application had shorter terminal shoots and made a smaller gain in trunk circumference than did the trees which did not receive nitrate of soda. When four pounds of nitrate of soda were applied the trees produced longer terminal shoots and gained more in trunk circumference than did those which received no nitrogen or those which had two pounds applied. In this case the yield was not in proportion to the amount of growth made. This is more clearly brought out where the trees receiving the six pound applications are considered. These trees produced but little longer shoots and gained but .36 of an inch in trunk circumference more than did those trees not receiving nitrogen yet they yielded 254.82 pounds more fruit. In this case as with those trees receiving the two pound applications of nitrate of soda, tree growth has not been in proportion to yield of fruit. In other words, the production of fruit has reduced tree growth or dwarfed the trees Why those trees receiving the two and six pound application should respond in this way, and those getting the four pounds should make more growth than either of the two other groups is a matter the writer cannot answer. The only explanation that can be offered at this time is that in this experiment nitrogen was a limiting factor in fruit production. Hence, the application of two pounds of nitrate of soda caused more fruit buds to be set and perhaps aided in a better set of fruit which increased the yield. When four pounds were applied there was sufficient nitrogen available for both increased growth and yield The trees by the heavier application were forced into a more vegetative condition and consequently set fewer fruit buds with a resulting smaller per cent of fruit. Those trees receiving the six pounds of nitrate of soda have had their top root ratio unbalanced apparently in that the heavier applications produced conditions causing larger tops in proportion to their roots. With this condition and the moisture condition of the soil under which the experiment was carried on, top growth would have been made rapidly early in the spring and as the drier weather came on growth would be checked. Thus, an earlier maturing of the wood and the formation of more fruit buds would result. In this way it would be quite possible and probable to secure a set of more fruit buds, to obtain more fruits set and carry them through to maturity, with only a little more tree growth than those trees not receiving nitrogen. The data for shoot growth, gain in trunk circumference, set of fruit buds, and yield of fruit seems to substantiate this explanation.

SUMMARY

1. There is a fair degree of correlation between the gain in trunk circumference and the yield of fruit in peach trees.

2. Length of terminal shoot growth is equally as well correlated with yield of fruit as is gain in trunk circumference.

3. There is very little correlation between gain in trunk circumference and yield or between length of shoot growth and yield for any one season.

4. Nitrogen was found to reduce the degree of correlation between length of shoot growth and yield or gain in trunk circumference and yield as compared with trees not receiving nitrogen.

5. Nitrogen lessens the degree of correlation between tree growth and yield of fruit of peaches by increasing the yield at a relatively greater rate than it increases tree growth as compared with trees not receiving nitrogen.

6. One instance was found where nitrogen increased growth at a greater rate than it did yield.

Conclusion

The length of the terminal shoots produced, and gain in trunk circumference used singly or together in conjunction with yield of fruit are valuable aids in measuring the response of peach trees to varying treatments and in the correct interpretation of results of field experiments with peaches.

Some Observations on the Response of Peach Trees to Summer Pruning

By H. L. Crane, *West Virginia University, Morgantown, W. Va.*

CHANGES in the chemical composition of fruit trees have been considered as taking place slowly, or that such small quantities of food materials are formed and accumulated in the tissues that their presence is difficult to determine quantitatively between trees receiving different treatments. The only reason the writer has for offering this paper is to point out that in some cases the response of peach trees may be observed very quickly following a treatment which disturbs the equilibrium of the trees.

The peach orchard under observation was planted on a poor soil in the spring of 1916. The soil belongs to the DeKalb silt loam, yellow in color, practically free from sand and gravel, surface soil shallow and originally never very fertile. The orchard site had been cropped for years, with corn mostly, before the trees were planted. Clean cultivation with an annual cover crop of rye has been practiced. An application of 300 pounds of 16 per cent acid phosphate was made at the time of seeding the cover. The orchard from the very start has been used as a pruning experiment, testing out varying degrees of severity of dormant and summer pruning. All the trees were headed at a height of twenty inches and were trained to three main scaffold limbs. The trees made a good growth until the summer of 1919 when they produced a heavy crop of fruit. Since that time they have had the appearance of trees suffering from nitrogen deficiency, having yellow leaves, slender growth, and setting few fruit buds which have not been as hardy as buds on more healthy trees. Nitrogen carrying fertilizers were not applied until the spring of 1924. That the trees in this orchard were deficient in nitrogen was

conclusively shown by comparison with adjacent trees receiving nitrogen at the time, and by their response to the 1924 spring application.

To save time in the formation of the main framework of the trees, in certain of the blocks in the experiments, summer pinching was practiced to cause branching at the desired points. In other blocks, summer pinching was done in the early summer, or late summer, and in others pinching was done repeatedly with the idea of checking the growth of certain branches and causing a heavier set of fruit buds. This pinching, or summer pruning, consisted of removing about one inch of the terminal shoot growth with a sharp knife.

During the summer of 1920 it was observed that the trees which had been pinched one or more times during the summer bore foliage which was of a much darker green color than did adjacent trees which had not been pinched.

On June 27, 1921, a block of Salwey peach trees were pinched. The following morning when work was resumed the trees which were pinched the day before bore foliage of a much darker green color than did the adjacent unpinched trees. Feeling that the removal of the growing tips was responsible for the color changes in the foliage, every other tree in a row was pinched. In from one to two hours from the time of pinching a tree a very marked change in the color of the leaves could be seen between the pinched and the unpinched trees. In several cases one or two of the scaffold limbs were pinched and within the short time of approximately one hour very pronounced color changes in the foliage could be observed between the pinched and unpinched limbs. Foliage on the limbs from which the growing tips had been removed took on a dark green color similar to trees fertilized with heavy applications of nitrate of soda, while the foliage on the unpinched branches, even on the same tree, remained a light yellowish green.

Shoots from limbs on the same tree which were exposed to the same light conditions as near as possible were taken just before pinching and one hour after. These were placed in water and kept in the dark for 20 hours. Corresponding leaves from several shoots were cleared with alcohol and then treated with potassium iodide plus iodine. The leaves from the pinched shoots contained much more starch than the unpinched ones. Microchemical examination showed the tissues of the leaves and adjacent wood tissue to be congested with starch, while similar ones unpinched contained much smaller amounts. After three weeks similar leaves and shoots were again tested for relative amounts and distribution of starch in the pinched and unpinched branches. No apparent differences could be found. The starch congestion had disappeared with the shoots resuming growth. However, the leaves on the pinched branches retained their dark green color for several weeks longer and in some cases until leaf fall.

Apparently, removing the growing points caused accumulation of carbohydrates by removing the points where most of the elaborated food was being used. The amount of nitrogen available for the trees remained the same after pinching as before and as it was not used in

growth more accumulated. This increased nitrogen was responsible for the change in color of the foliage. It is doubtful if the increased moisture available for the trees, due to the removal of the succulent and rapid transpiring growing points, affected the color changes of the foliage or the accumulation of elaborated food or food materials. Water had not been deficient prior to or after the pinchings were made, as the weather records showed heavy thunderstorms every day or so, while our records showed that the soil was wet and that the daily temperatures were high with the nights cool.

In the latter years of these experiments pinching has not increased the set of fruit buds or the yield of fruit. It has, however, caused numerous laterals to be formed and in the case of pinching made in late summer, or when the pinching was repeated several times during the growing season, shoot growth has continued later in the summer. This has presumably used up the stored food until after the period of fruit, bud initiation was over. The accumulation of starch in the leaves caused by the removal of the growing points would inhibit the formation of more starch, so in the end pinched trees probably contained less stored food per unit of wood than unpinched trees.

These observations have been of considerable interest to those who have known about them, largely because of the extreme shortness of time elapsing between the time of treatment and the response of the tree as shown by the very marked color changes of the foliage. Judging from these observations there must be little time elapsing between the time a treatment is given a tree and its response to it

Autumn Development of Peach Fruit Buds

By J. S. Bailey, *Massachusetts Agricultural College, Amherst, Mass.*

IN Massachusetts, which is on the northern limit of the peach producing area of this country, the greatest obstacle to successful peach growing is lack of bud hardiness, especially in commercial varieties such as Elberta and Early Crawford. In order to breed the bud hardiness of a variety like Greensboro into these more tender budded varieties, it is desirable to know why the buds are killed and what bud hardiness is.

Whitten (12) gives four causes for the winter killing of peach buds; first, imperfect ripening or lack of maturity; second, starting of the buds into growth and subsequent killing by low temperature; third, very low temperatures and consequent severe freezing; fourth, sudden changes of temperature.

The first cause of bud killing, immaturity, is probably the most important in most peach growing sections, though not in Massachusetts, as it is the one given oftenest and stressed most by investigators in the field of winter killing and hardiness of fruit buds. Both Whitten (12) and Chandler (4) give immaturity as the cause of winter killing of peach fruit buds in Missouri, Bradford (2) reports a case of the killing of apple fruit buds when peach fruit buds were unhurt, a

phenomenon which he attributes to lack of maturity in the apple buds. English (6) working with box-elder, white ash, and black walnut trees decided that bud killing was due to immaturity.

The second cause of fruit bud killing, the "January thaw," is probably almost as important as the first. Maynard (8) and Bartlett (1) give it as a cause of peach bud killing in Massachusetts. Whipple (11) gives it as a possible cause of the killing of apple fruit buds in Montana. Chandler (5) reports a case of peach bud injury in New York which it is not clear whether due to the first or second cause.

The third cause, very low temperatures with consequent severe freezing, is probably not as important as the first two, although it is probably more important in Masschusetts and other northern peach growing states than in those farther south. Twice in the last 10 years in Massachusetts this has caused the loss of practically the entire crop.

The fourth cause, sudden changes of temperature, is probably not as important in the killing of peach buds since no specific cases have been reported. However, it has been reported in the case of other plant tissues. Potter (9) and Carrick (3) agree that, "A rapid fall in temperature is shown to increase the freezing injury in apple roots."

A case of fruit bud killing has occurred in the experimental peach orchard at Amherst which none of these causes explains satisfactorily. In the winter of 1922-23 a temperature of—15°F on February 2 did almost no damage, while in the winter of 1923-24 a temperature of—14°F on January 26 destroyed practically the entire crop. As bud-hardy a variety as Greensboro had only 11 per cent of live buds after the freeze. There had been no warm weather either year to start the buds into growth and apparently they entered the winter in a fairly mature condition

The following table gives a clue to the reason for this difference in bud killing. It gives the departures of the mean monthly temperatures from the 25 year mean and the departures of the presence of sunshine from the 25 year mean.

	Temperature Departures			Per cent Sunshine Departures		
	September	October	November	September	October	November
1922	+3.9	+1.9	+1.6	+9.1	+8.4	—4.6
1923	+3.8	+1.8	+1.7	+7.1	+20.4	+1.7
1924	—2.1	+1.1	+1.9	—2.9	+17.4	+3.4

It appears that any development of buds late in the season of 1923 cannot be accounted for by difference in air temperatures, but that the excessive amount of sunshine in October 1923 offers an explanation.

In his work in Missouri Whitten (12) showed that the temperature of dark colored peach twigs would vary several degrees in sunlight and shade. Harvey (7) by measurements of cambium temperatures by the thermo-electric method found that a black bark may be 22°F above air temperature in bright sunlight. This gives reason to believe that the excessive sunlight in October, 1923, caused the peach

fruit buds to develop to a stage in which they were susceptible to freezing. Such an explanation agrees with Roberts (10) work on cherries for he says, "The extent of winter killing of the blossom buds of the cherry is largely in direct relation to the amount or degree of their development at the beginning of winter."

That a development of the fruit buds actually did take place was found by tracing this development from week to week through the fall of 1923 and 1924. The buds developed until the latter part of November, but most of the development took place during October. Figures (1–6) in the illustration show this for the two varieties Elberta (1–3) and Greensboro (4–6).

Figures 1 and 4 show the stage of development of Elberta and Greensboro on September 15. The positions of the future stamens and pistils were at that time indicated by mere swellings of the meristematic tissue. On November 3 (Figures 2 and 5) the pistils were well formed and the stamens developed far enough so that the anthers and filiments were plainly distinguishable. After that practically no development took place as the drawings of the buds cut on December 1 (Figures 3 and 6) show.

By comparing the crop estimates for Massachusetts for the past 35 years with the minimum temperatures of the preceding winter in different parts of the state, and eliminating cases where killing was due to very low temperatures, it seems quite possible that in some cases there is a correlation between winter killing of peach buds and excessive sunshine in October. Furthermore, the fruit buds this fall after a sunshine departure of + 17.6 per cent for October are just as far advanced as they were in 1923 at this time.

In conclusion it may be stated that from the evidence secured thus far the killing of peach fruit buds seems, in some cases not otherwise explained, to be correlated with an excess of sunshine in October which causes them to develop to such a degree as to be susceptible to winter killing by temperatures of from minus 10°–15°F. This work is being continued in order to secure more data on the problem.

1. Bartlett, G. Peach Buds Winter Killed, Horticulturist, Vol. 1, p. 549 (1847).

2. Bradford, F. C. Observations on Winter Injury—Early and Late Winter Injury. Mo. Res. Bul. 56 (1922).

3. Carrick, D. B. Resistance of the Roots of Some Fruit Species to Low Temperature. Cornell Univ. Memoir 36 (1920).

4. Chandler, W. H. The Killing of Plant Tissue by Low Temperature. Mo. Res. Bul. 8, (1913).

5. Chandler, W. H. Some peculiar Forms of Winter Injury in New York State during the Winter of 1914–15. Proc. Amer. Soc. Hort. Sci. 12:118 (1915).

6. English, L. W. Rpt. of the Horticulturist, Vt. Expt. Sta. Rpt. 1897–98, p. 302.

7. Harvey, R. B. Importance of Epidermal Coverings. Bot. Gaz. 67:441 (1919).

8. Maynard, S. T. Agriculture of Massachusetts, p. 348, Boston (1884).

Fig. 1

Fig. 4

Fig. 2

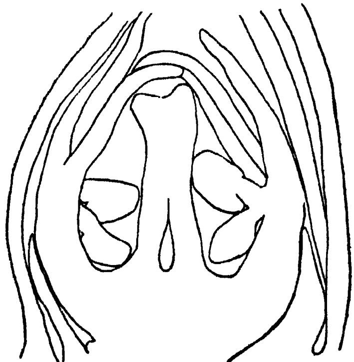


Fig. 5

Fig 3

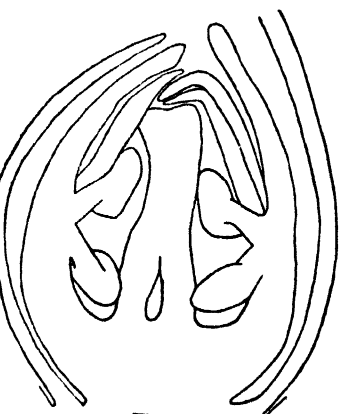


Fig 6

PLATE II. Plate of Development of Peach Fruit Buds

Fig. 1	Elberta on September 15, 1924.
Fig. 2	" " November 3, 1924.
Fig. 3	' " December 1, 1924.
Fig. 4	Greensboro on September 15, 1924.
Fig. 5	" " November 3, 1924.
Fig. 6	" " December 1, 1924.

9. Potter, G. F., Experiments on Resistance of Apple Roots to Low Temperatures. N. H. Expt. Sta. Tech. Bul. 27 (1924).
10. Roberts, R. H. The Development and Winter Injury of Cherry Blossom Buds. Wis. Expt. Sta. Res. Bul. 52 (1922).
11. Whipple, O. B. The Winter Injury to Fruit Buds of the Apple and Pear. Mont. Expt. Sta. Bul. 91 (1912).
12. Whitten, J. C. Winter Protection of the Peach. Mo. Expt. Sta. Bul. 38 (1897).

Correlation of Root and Top Growth of the Concord Grape and Translocation of Elaborated Plant Food During the Dormant Season*

By H. W. Richey and Hugh A. Bowers, *Iowa State College, Ames, Iowa*

A GROWTH study of the Concord grape vine was first formulated by the senior writer while a member of the Horticultural Department of the West Virginia University in 1917. A leave of absence was granted in 1919–1920 and certain phases of the work were carried on at the University of Chicago. The following year the work was started by the writer at the University of Maryland. Upon taking a position at the Iowa State College in 1921, various studies dealing with the growth of the grape were immediately started at that institution. This article, therefore, will only be considered as a progress report based on several years' close observations and two years' detailed experimental results. The investigation is being continued and when sufficient and satisfactory data have been obtained will be published by the Iowa State College.

This study was started first to secure some information as to the amount of top and root growth made by newly set grape vines when the top is confined to one or two shoots during the growing season; and second to ascertain if there is an appreciable transfer of elaborated plant food from the canes to the roots, or from the roots to the canes during various periods of the dormant season. The older recommendations for pruning the young vine are to cut it back to two buds and later to rub off one shoot in case two developed. More recently the recommendation to rub off one of the shoots has been discontinued. It is thought by some that shortly after leaf fall there is a decided translocation of elaborated food from the canes to the roots where it is stored. It is obvious that the first object has a bearing on the amount of pruning to give the young vine, and the second object may have some influence on the time of pruning and taking cuttings during the dormant season.

*The work reported in this paper was done by J. C. Schilletter and the writer in 1922–23 and by Hugh A. Bowers and the writer in 1923–24.

In this brief article no attempt will be made to review the literature pertaining to the subject. Suffice it to say that the literature dealing with the subject has been freely drawn upon whenever it might have a bearing on the problem.

Materials and Methods

Well-grown, uniform, one year old Concord grape vines were secured from T. S. Hubbard Company, Fredonia, New York. The plants were always in a good dormant state at the time they were planted. Preparatory to planting, the roots were cut back quite severely and the tops restricted to one cane which was reduced to three or four buds.

In order to arrive at the approximate weight of a pruned vine preparatory to planting, the cane and trunk of 10 representative pruned vines were separately measured in inches. The 10 vines were then separated into canes, trunk or stem, and roots. The canes, trunk or stem, and roots, were then weighed separately in grams. From this one could determine fairly accurately the average weight of a definite length of a cane and trunk. Then knowing the length of the cane and of the trunk of each vine and the total weight of the vine, one could compute the weight of the cane and the weight of the trunk, and, by subtraction, obtain the weight of the roots. The dry weight was ascertained in a similar fashion.

The vines, after being pruned and weighed, were planted in wooden tubs 30 inches square and 36 inches deep. The soil used was ordinary composted blue grass sod that had grown on a fertile loam soil and was similar to that used in our greenhouse benches.

Vines with one and two canes were desired and in order to insure such growth three or four buds were left on the pruned vine. Immediately after the buds started growth those not required were rubbed off. The shoots were carefully tied from time to time during the growing season so that the growing point would not be injured. Any side shoots that formed were immediately removed, thus confining the vine to either one or two unbranched shoots. During the present year, data for which are not included in this paper, the side shoots were not removed.

At two or three periods during the growing season the separate canes on each vine were measured and the leaves counted. Near the end of the growing period the leaf area of each shoot was approximated by determining the average size of large, medium and small leaves and multiplying this average by the number of leaves on each shoot that fell in each class. It was found that the total leaf area was quite closely correlated with the number of leaves as there was no appreciable difference between the percentage of large, medium and small leaves on the different shoots. We thus had the weight of the cane, trunk and roots of the vine at the time of planting, the length of growth made by each shoot and vine, and the amount of leaf area of each shoot and vine.

Digging the Vines

In order to study the correlation of growth between the top and roots it was necessary that the separate weight of the root, stem and canes, be obtained for each vine. Consequently, at the time of digging, the canes were removed from the vine, cut immediately into a weighed Erlenmeyer flask and the green weight determined. A small quantity of reprecipitated calcium carbonate was added, together with sufficent redistilled 95 per cent alcohol to cover the tissue. The tissue was gently refluxed for about one hour. It was then tightly stoppered and stored for chemical analyses.

After removing the canes from the vine the tub was tipped on its side and the soil washed from the roots of the plant by means of a strong jet of water. The root system was thoroughly washed, dried of apparent moisture by means of an electric fan and the roots separated from the stem or trunk of the vine. The roots and trunk were then treated separately the same as the canes. We thus had the green weight of the cane or canes, the green weight of the trunk or stem, and the green weight of the roots after the vine had grown in the tub for one year. The tissue was preserved in the same fashion as that of the canes for moisture determination and chemical analyses.

Since a study was being made of the possible translocation of elaborated plant food from the canes to the stems or roots; from the stem to the canes or roots; and from the roots to the stem or canes during various periods of the dormant season, the vines were dug at six different times during the dormant period. Four or five vines were removed at each time. The first digging occurred immediately after the normal leaf fall. The second digging followed in two weeks with the subsequent diggings at four week intervals. The last digging was made before appreciable sap flow began. All of the vines were dug, separated into their respective parts, weighed, and preserved in the same fashion for moisture determination and chemical analyses.

Chemical Studies

In this brief discussion no explanation will be made of the methods used in the chemical determinations. Suffice it to say that recognized accurate methods were used and the entire method of procedure was approved by several reliable plant chemists. Determinations were made of the per cent of moisture, free reducing substances, disaccharides, total reducing substances and polysaccharides or "starch." Possibly a designation more accurate than polysaccharides or starch would be alcohol insoluble, acid hydrolyzable substances. It has been impossible to study the total nitrogen content, but hereafter this determination will be included.

Discussion of Results

The lengthy and complicated tables and charts will not be presented in this paper. Only a brief discussion of the results obtained will be given and one summarizing chart will be shown for each group of chemical determinations.

The chemical analyses ran comparatively uniform in the vines dug at the same time. There were small variations in the analyses of the different vines, but, as a rule, the variations were not appreciable. There were comparatively large variations in the analyses of vines dug on different dates, although in a few cases the variations were small between individual vines dug on different dates.

Chemical Analyses

Free reducing substances

There was a steady increase of free reducing substances in the canes, trunk and roots from October to January at which time the greatest amount was found of any time during the period covered by the study. This high point in January was followed by a decrease in February which decrease continued to March 22 for the trunks, but was followed by an increase in the canes and roots for the same period. These changes in percentage of free reducing substances for the three different parts of the vine vary quite similarly.

Sucrose†

In studying the chart, one observes that there was a very small decrease in the sucrose in both the canes and roots from October to November. There was then a rather decided increase until the determination on January 10 which was followed by just as decided a decrease until February after which there was again an increase. It is to be noted that active growth of the cuttings placed in the greenhouse started at about this time. It will be observed that the curve representing the sucrose of the stems was more regular. There was a steady increase from October to December, then no measurable change for a month and then a steady decline until the last analyses in March.

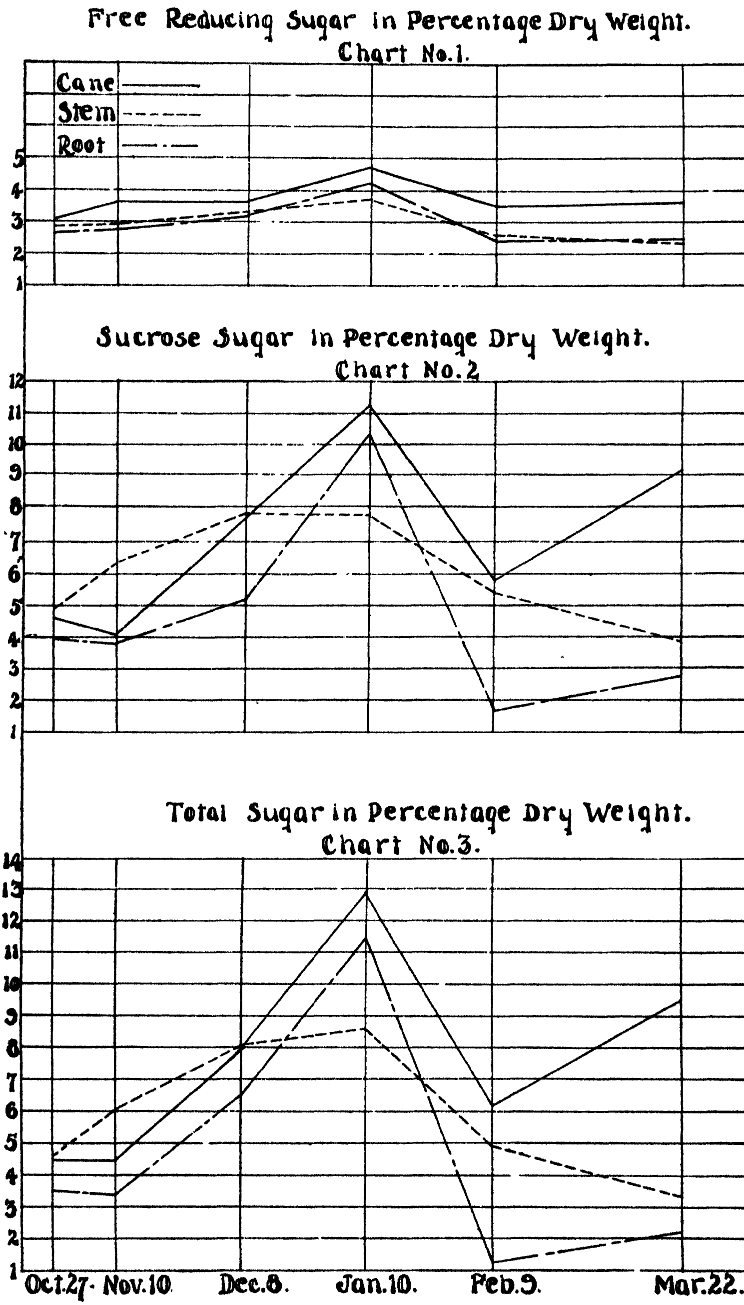
Total Sugars

As would be expected from the small differences in free reducing substances in the different parts of the vine, the curves for the total reducing substances would correspond very closely to those representing the sucrose, and the chart shows this to be the case. In all three charts, free reducing substances, sucrose and total sugars, the highest percentage of all three parts of the plant, stem, cane, and roots, was reached at the analyses of January 10.

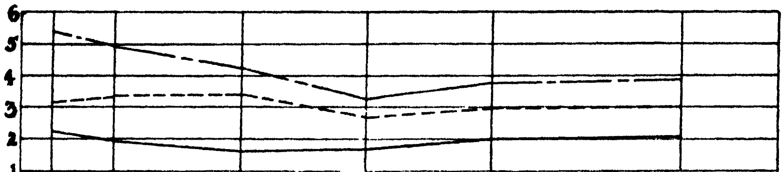
Polysaccharides (Starch)‡

The chart shows that for the canes there was a decrease in polysaccharides to December and then a slight rise until February, with March showing no change over February. The curve for the roots was much the same as that for the canes except that the initial decrease continued until the January period, after which a slight gradual increase continued until the March determinations. The

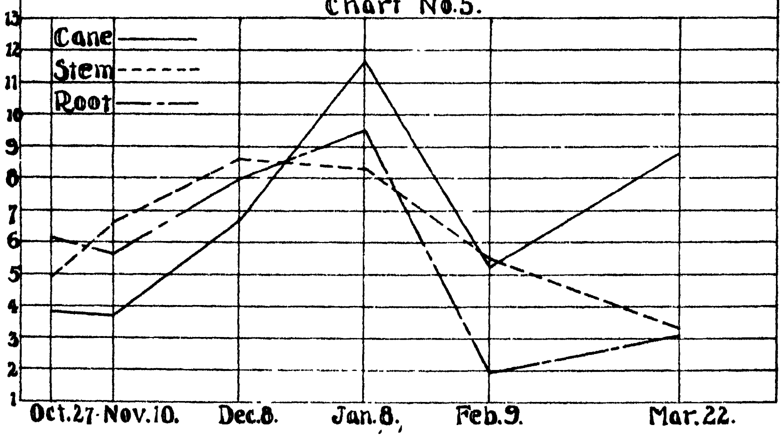
†Alcohol soluble acid, hydrolyzable substances.
‡Alcohol insoluble, acid hydrolyzable substances.


Free Reducing Sugar in Percentage Dry Weight.
Chart No.1.
Cane
Stem
Root
Sucrose Sugar in Percentage Dry Weight.
Chart No.2
Total Sugar in Percentage Dry Weight.
Chart No.3.
Oct.27. Nov.10. Dec.8. Jan.10. Feb.9. Mar.22.

Polysaccharides in Percentage Dry Weight
Chart No.4



Total Carbohydrates in Percentage Dry Wt.
Chart No.5.



polysaccharides in the stem, on the other hand, increased slightly from October to December, after which the curve closely parallels that for the roots. During the time at which there was a decrease in polysaccharides there was an increase in sugars which probably is accounted for by hydrolysis of the polysaccharides.

On the basis of percentage of dry weight the Concord grape vine stored most of its reserve carbohydrates in the form of "starch."

Total Carbohydrates

The chart representing the total carbohydrates is much similar to that for the total sugars. The curves for the canes and roots were much the same. The quantity for the canes remained the same for the first two determinations after which there was a decided rise for the determinations of December and January. This rise was followed by just as pronounced a drop for the February analyses, which drop was followed by another rise. The total carbohydrates in the stems increased steadily until December and decreased slightly until January, after which there was a steady decline until the time of the last determinations on March 22.

From the time of the first analyses, October 27, to the analyses of January 8, the percentage of total carbohydrates increased in the canes, stems, and roots. This increase was followed by a rather marked decrease of total carbohydrates in all parts of the vine. This high point, and following decrease, coincided quite closely with the initiation of growth of the plants that previously had been placed in the greenhouse under favorable growing conditions. In these plants the rest period was over. A very similar curve to that of total carbohydrates is shown for free reducing, disaccharide, and total sugar content. The high point, January 8, in these charts, is a low point in the polysaccharide (starch) chart which possibly indicates hydrolysis. There was a rather large increase in total carbohydrates in all parts of the plant at the time of the January 8 analyses. The only explanation offered for this large increase in the entire plant at this time, is that some reserve material, not hydrolyzed by the chemical treatment given, had been hydrolyzed by the enzymes of the plant.

The evidence, presented by the chemical analyses, does not justify one in concluding that there was a translocation of carbohydrates from the canes to the roots, or from the roots to the canes, during the dormant season.

Growth Studies

In order to have some idea as to the time of completion of the after-ripening, or dormant period of the vines, cuttings were taken from the field at intervals of two weeks and placed in a greenhouse under favorable conditions for growth. Growth, as indicated by these cuttings, apparently was initiated sometime from the first to the fifteenth of January. It is interesting and possibly significant that the chemical analyses of January 8 showed the highest percentage of free reducing substances, sucrose, total sugars, and

total carbohydrates, in the canes, stems and roots of the vines, than for any other of the six times of analyses. The polysaccharides were slightly less at this time in the stem and roots than at any time previous. The polysaccharides in the canes were less at this time than they had been in October and November, but very slightly more than in December. The decrease in total carbohydrates following the January analyses, may be accounted for in part by the utilization of carbohydrates by the increased activity of the plant.

The number of leaves varied with the number and length of the canes. The leaf area varied in a similar fashion as the percentage of large, medium and small leaves did not vary appreciable on the various vines, irrespective of whether the vine had one or two canes or whether the canes were long or short.

The average total growth in inches of the vines with but one cane was less than that of the vines with two canes. The average number of leaves and the average leaf area were larger in the latter than in the former case. The larger the number of leaves and the longer the canes the greater the weight of the vine.

It was found by measurement of the growth in inches, and by measuring in wet and dry weight, that the greater the cane growth the larger the root system. There was not a direct proportional correlation between the growth of the tops and the growth of the roots but the plants with the largest amount of top growth had the largest root systems.

The caliper of the single cane was always greater than the caliper of either of the canes on the vines trained to two canes.

Thus it appears that on the average the young Concord grape vine with two growing shoots is a larger vine than the vine with but one growing shoot. The first vine has a larger number of leaves, a greater leaf area, a longer cane growth and a greater green and dry weight of both canes and roots. The caliper and length of the individual cane, however, are greater than the caliper and length of either of the canes on the vines having two canes.

Conclusions

From the work done so far on the Concord grape vine it appears as if there is no appreciable transfer of carbohydrates from the canes to the roots during the dormant season so the time of pruning and the time of taking cuttings would not be influenced as they would be if such a translocation did take place. It appears further that a larger root system is produced on the newly set vine that has two growing shoots than on the vine that has but one growing shoot.

Summary

The evidence does not justify one in concluding that there is a translocation of stored plant food from the canes to the roots or from the roots to the canes during the dormant season. There is an indication that there may be a slight translocation from the stem to both the root and canes after the vine has passed through its dormant period.

From the time of the first analyses, October 27, to the analyses of January 8, the percentage of total carbohydrates increased in the canes, stems, and roots. This increase was followed by a rather marked decrease of total carbohydrates in all parts of the vine. This high point, and the following decrease, coincided quite closely with the initiation of growth of the plants that previously had been placed in the greenhouse under favorable growing conditions. In these plants the rest period was over. A very similar curve to that of total carbohydrates is shown for free reducing, disaccharide, and total sugar content. The high point, January 8, in these charts, is a low point in the polysaccharide (starch) chart which possibly indicates hydrolysis. There was a rather large increase in total carbohydrates in all parts of the plant at the time of the January 8 analyses. The only explanation offered for this large increase in the entire plant at this time is that some reserve material, not hydrolyzed by the chemical treatment given, had been hydrolyzed by the enzymes of the plant.

On the basis of percentage of dry weight the Concord grape vine stored most of its plant food in the form of starch (polysaccharides).

There was not a proportional correlation between top growth and root growth of the two year old vines, but the vines with the largest tops had the largest root systems.

Vines with the greatest leaf area made the most growth.

The two-cane vines produced more top and more root growth than the vines with but a single cane although the caliper of the single cane was greater than the caliper of either of the canes on the vines with two canes.

Seasonal Changes in the Chemical Composition of the Concord Grape Vine

By A. L. SCHRADER, *University of Maryland, College Park, Md.*

RECENT studies at Maryland of the relation between growth and fruiting habits of the Concord grape raised a question in regard to the role which chemical composition might play in determining the observed responses. It seemed desirable, therefore, to make a study of the seasonal changes, particularly of carbohydrates and nitrogen, which would occur in nodes one to nine of the new shoots of the vine that become the fruiting wood for the following season. A knowledge of these changes and of the reserves which occur in the cane then might be used to facilitate other chemical studies of various responses of the vine. It was further hoped that the above study would throw some light on the observed differences in the fruiting capacity of the various nodes of the canes, especially if the fruit borne on the second, third and fourth nodes of the growing shoot might influence the chemical composition of those respective nodes and explain the low fruiting capacity of these nodes in the following

season. It was also desired to ascertain if the cane actually stored up much organic reserves, or if these materials were translocated to the roots, and especially if any transportation to the roots occurred during the dormant season.

Methods

Sampling. All samples were taken on a clear day about 10 o'clock in the morning. Ten to 12 shoots on one year wood were taken at random except that care was used to select shoots of approximately the same length and diameter, each bearing or having borne blossom clusters or fruit on nodes two, three, and four. All leaves were removed at once in the field and the shoots were taken to the laboratory. Nodes one to nine inclusive (counting from basal end) were taken from each shoot retaining about one inch of the internodes with each node. Analagous nodes of the various shoots were then placed together to comprise a sample, so that a sample of each node of the shoot up to and including the ninth node was obtained. Each sample was weighed for green weight and immediately dropped in hot alcohol which was then refluxed for 30 minutes at 70°C. The samples were prepared for analysis by decanting off the preserving extract which was made up to 200 cc. volume and drying the solid material in an oven 80°C. for twenty-four hours. The dry material was ground to pass a 40 mesh sieve.

Samples taken during the dormant season were simply cut up in small pieces and dried in an oven at 85–90°C. for 72 hours.

Reducing Substances. About a three gram portion of the ground sample, well dried, (aliquots of dry material and preserving extract when necessary), was placed in a Sohxlet siphon extraction apparatus and extracted for three hours with 150 cc. of 50 per cent alcohol. The alcohol was removed from the extract on a water bath and water was added to about 150 cc. volume. Proteins were then precipitated from the extract with a few drops of saturated solution of neutral lead acetate. The extract was made to 250 cc. volume, filtered, and the excess lead removed with anhydrous sodium carbonate. The reducing power of the extract was then determined by the Bertrand modification of the Munson-Walker method as given by Matthews' Physiological Chemistry, 1921. The result was expressed in terms of dextrose.

Total Sugars. A 50 cc. portion of the sugar extract was hydrolyzed by hydrochloric acid (5 cc. of concentrated acid) at room temperature for 24 hours, neutralized with anhydrous sodium carbonate and made up to 100 cc. volume. The reducing power of this solution was determined as in the method for reducing substances and reported as dextrose.

Sucrose. The difference between the reducing substances and total sugars is reported as sucrose in terms of dextrose.

Hydrolyzable Materials. About a half gram portion of the dried residue from the sugar extraction was hydrolyzed by refluxing with hydrochloric acid (10 cc. of concentrated acid to 100 cc. of water) for two and a half hours. This extract was neutralized with anhydrous sodium carbonate and made up to 250 cc. volume, and the reducing power was determined as in the above procedure. The result is expressed in terms of dextrose.

Total Nitrogen. The Kjeldahl method with a modification by Gunning to include nitrates was used in this work.

Soluble Materials. The difference in weight between the dry material before extraction with alcohol and the dried residue after extraction represents the soluble material.

Results

The results of the analyses given in Table I., represent the average of the analyses of the various nodes of the shoot. Thus, the chemical changes which are noted in this table may be considered as the changes which occur in the growing shoot, or at least in that part of the shoot from node one to nine inclusive. The percentages given under the date of May 10 are averages of analyses of nodes one to three and at this time the shoots were about 12 inches in length. The percentages under the date of May 25 are averages of analyses of six nodes (one to six) and the shoots were then about 23 inches in length. All the subsequent percentages are averages of nine nodes (one to nine).

TABLE I

Seasonal Changes in Grape Shoots. Average of Analyses of Nodes One to Nine (Percentage on Dry Weight Basis)

Date of Sample	May 10 1923	May 24 1923	June 14 1923	July 14 1923	Sept. 1 1923	Oct. 18 1923	Jan. 11 1924	Mar. 28 1924	Apr. 3 1924
Moisture	88.14	86.52	79.72	70.64	48.79	46.67	45.72	45.76	42.92
Dry matter	11.86	13.48	20.28	29.36	51.21	53.33	54.28	54.24	57.08
Hydrolyzable Materials	12.08	16.03	20.12	21.95	32.12	31.15	23.07	29.90	27.52
Total Sugars	9.81	5.63	5.63	6.09	2.26	2.55	7.94	2.94	5.14
Sucrose	3.88	1.38	1.83	1.69	0.31	0.85	3.17	1.31	1.14
Free Reducing Substances	5.93	4.25	3.80	4.40	1.95	1.70	4.77	1.63	4.00
Total Nitrogen	3.01	2.51	1.07	0.693	0.593	0.698	0.803	0.974	0.710
Total Carbohydrates	21.89	21.66	25.75	28.04	34.38	33.70	31.01	32.84	32.66
Soluble Material	36.30	30.18	17.90	15.50	8.84	10.93	21.78	11.90	12.41

The changes which take place in the shoot as a whole as typified by Table 1 and the changes which occur in the individual nodes may be best discussed by considering each material separately.

Dry Matter. The shoot as a whole increases in dry matter according to the typical growth curve. Taking the individual nodes, it is found that in the early part of the growing season, the basal node has the greatest percentage of dry matter and the most distal node has

the least percentage of dry matter. However, by the middle of July the nodes one to nine inclusive were practically alike in percentage dry matter with slightly greater percentage in nodes four, five and six.

Hydrolyzable Materials. These materials increase rapidly in the early period of growth tending to follow the increase in dry matter, but by the middle of June this accumulation slows up in rate until the middle of July when a rapid increase in these materials is again noted until the 1st of September. In the early part of the growing season, the basal node has the highest percentage of hydrolyzable material while the most distal node has the least. This difference tends to disappear, for by June 14 nodes one to six inclusive had practically the same percentage of these materials. The ninth node continued to be lowest in percentage of these materials until October 18 when all nodes one to nine were nearly the same.

A very striking thing in regard to hydrolyzable materials occurred in January. A marked hydrolysis of these materials was noted with a corresponding rise in sugars, both sucrose and free reducing substances. Later, it was found that this reaction had reversed itself and hydrolyzable materials were again at nearly the former level.

Free Reducing Substances. These substances show a high percentage during the growing season with the highest point in the first stages of growth. During the dormant season these materials are relatively low on a percentage basis except at the time noted above in January when hydrolysis of polysaccharides occurs. With respect to individual nodes some consistent differences were noted during the growing season. In June and July it was found that nodes two, three and four (bearing fruit) were relatively low in reducing substances compared to nodes five, six and seven.

A rise in reducing substances occurred in July at the time when rapid accumulation of hydrolyzable materials was resumed.

Total Sugars and Sucrose. These substances followed rather closely the changes detailed for reducing substances. Sucrose reached a very low point in September.

Total Nitrogen. The percentage of total nitrogen was greatest in the early stages of growth and decreased rapidly during the growing season. A slow rise in nitrogen occurred during the dormant season.

Changes Occurring in the Roots and Tops of One Year Old Grape Vines During the Dormant Season

The results of this study are given in Table II. The percentages of nitrogen represent an average of analyses of four vines for each date. The percentages of the various carbohydrates are based only on the analysis of a single vine for each date.

The above analyses show changes in the tops which are similar to the changes recorded in Table I. Hydrolysis of polysaccharides occurs toward mid-winter followed by a reverse of this change in late

winter before growth starts. This hydrolysis is more marked in the tops than in the roots. Roots had a greater content of hyrolyzable materials and total polysaccharides at every date except March 9. Expressed in terms of absolute values for polysaccharides the roots had a much greater content of these materials at all times since the

TABLE II

Changes Occurring in Roots and Tops of One Year Old Concord Grape Vines During the Dormant Period
(Percentages on Dry Weight Basis)

Date of Sample	October 4 1921		November 1 1921		December 8 1921		March 9 1922	
	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots
Dry Matter	54.1	41.5	55.1	49.3	56.5	48.4	53.1	43.6
Hydrolyzable Materials	33.30	35.93	29.00	39.45	25.30	37.74	39.56	35.74
Total Sugars	2.93	1.13	4.96	1.66	7.88	2.24	4.01	0.95
Sucrose	1.52	0.59	3.06	0.86	3.52	1.24	0.18	0.30
Free Reducing Substances	1.41	0.54	1.90	0.80	4.36	1.00	3.83	0.65
Total Nitrogen	0.953	0.234	1.047	1.651	0.988	1.548	0.840	1.814
Total Carbohydrates	36.23	37.06	33.98	41.11	33.18	39.98	43.57	36.69

roots constituted about 70 per cent of the total dry weight of the vine. The percentage of reducing substances was always greatest in the tops and the same relation held for sucrose with the exception of March 9 when sucrose showed a greater percentage in the roots, although it will be noted that sucrose was very low in both roots and tops.

A very striking feature in Table II is the very great increase in percentage of total nitrogen in the roots in early fall. This percentage of nitrogen then remained fairly constant except for a slight rise in late winter.

DISCUSSION

The chemical analyses detailed in this paper furnish some interesting data on the carbohydrate reserve of the vine. Large amounts of carbohydrate reserves were found to be present in both roots and tops. Microchemical tests on canes during the dormant season indicate that starch comprises a large proportion of these reserves. No appreciable translocation of carbohydrates from tops to roots, or vice versa, occurs during the dormant season, contrary to the results of some French investigations. Hydrolysis of polysaccharides was noted in mid-winter especially in the canes which might have been misinterpreted as a translocation of carbohydrates.

From a practical standpoint, the fairly constant carbohydrate content of the cane during the dormant season would suggest that as far as carbohydrate reserves are concerned it makes little difference when pruning is done, or when cuttings are taken from the vine for propagation. Some preliminary studies with cuttings taken at intervals during the dormant season show no consistent differences due to time of taking cuttings, as regards growth or percentage set of cuttings.

A large proportion of carbohydrates and nitrogen of a one year old vine are found in the roots of the vine. The roots show both a greater percentage and absolute amount of these reserve materials. About 75 per cent of the total carbohydrates and 80 per cent of the total nitrogen of the young vine, was found in the roots. This high proportion of reserves in the roots may have some relation to the abundant growth of top which results even after the severe pruning to two buds which is usually practiced on the young vine at the beginning of the second season.

The fruit which is borne on the growing shoot strongly influences the accumulation of carbohydrate reserves as shown by the slow change in percentage of these materials while the fruit is developing in size, namely from June 1 to July 15. After the fruit has reached full size, carbohydrate reserves again accumulate in the cane. The nodes two, three and four upon which the fruit was attached in the canes studied showed a low percentage of free reducing substances on June 14 and July 14 as compared to nodes five, six and seven. This difference in free reducing substances may be associated with the low fruiting capacity of these nodes two, three and four. Studies are being made to ascertain if fruit bud differentiation occurs during the same period.

The cold temperatures of winter are evidently associated with the hydrolysis of polysaccharides as noted in these studies. Similar hydrolysis was found in cabbage on January 12, one day later than the grape sample, by V. R. Boswell of our department (unpublished data).

The increase in nitrogen content of roots of young vines during the dormant season probably represents an intake of nitrogen by the roots in early fall after leaf fall, and again in early spring. A slow translocation of nitrogen to the tops is apparent in the slow rise in percentage of nitrogen in the tops. This intake of nitrogen may have some significance in regard to fall application of nitrogen to fruit plants.

Conclusions

1. Quantitative changes in carbohydrates and nitrogen were followed in nodes one to nine of the grape shoot during the growing and subsequent dormant seasons.
2. Quantitative changes in carbohydrates and nitrogen were followed in roots and tops of one year old grape vines during the dormant season.
3. Carbohydrate reserves are present in large amounts in tops and roots of grape vines during the dormant season.
4. Roots possess the greater proportion of reserves of one year old vines.
5. The developing fruit evidently retards the accumulation of reserve carbohydrates.
6. Hydrolysis of polysaccharides occurs during mid-winter.
7. Nodes two, three and four (bearing fruit) are relatively low in free reducing substances in June and July.
8. Nitrogen is apparently taken up by the roots in large amounts after leaf fall.

Variations of Plat Yields in Field Experiments with the Grape and Their Interpretation

By F. E. GLADWIN, *Branch Experient Station, Fredonia, N. Y.*

IT is well known that tree and other fruits of like age and variety vary greatly in vigor and productivity. In our selective breeding work with the Concord grape, we have propagated many plants from cuttings taken from vines that were markedly superior in vigor and fruit yield. Yet, when plants from such vines came to the fruiting stage, it was found that the superior characters sought were not handed down to the progeny. Hence, it must be concluded that other variables made the superior vines. Differences in vigor and productivity of many tree fruits can be traced in many instances to the variability of the stocks on which they have been propagated. But, aside from these departures, the soil, exposure, topography, and insect and fungous depredations exert influences that quite often result in uneven fruit plantings.

Whether variability of plants comes from one cause or another, it would seem desirable that the experimenter should know something of the true nature of the population with which he is dealing.

Variations of individuals within a plat and, more often, of plats that should, because of like treatments, yield very closely, have long been the bane of the experimenter with fruit fertilizer tests. That he is aware that other factors than the treatment are operative, and that they are interfering with the correct interpretation of the data, is made plain through the following excerpts from fertilizer tests with fruits described in various publications.

"It would seem that the differences in yield between the series of plats under question were due to soil conditions, to the more vigorous condition of the trees, and to the variation between plats rather than to the addition of phosphorous and potassium in combination with nitrogen."

"The soil of plat X was slightly more fertile and better supplied with moisture than was plat Y, owing to the slight dip in the land."

"The effect of lime on the Check plats was insignificant. Plat 6 showed a loss, plats 12 and 13 a slight gain, and plat 22 a somewhat larger gain."

"The effects of fertilizers on the increase in trunk circumference in this experiment are not clear cut as many inconsistencies are evident from a study of the gains in trunk circumference in the various plats as compared with that of the nearest checks."

"It is true as previously noted on page 16 that these four plats were on slightly lower ground and received the wash from the other plats which probably accounts for the great similarity in yield."

"Also in many cases three treated plats intervene between the checks which might result in marked soil differences within the three plats."

"The most striking thing about the results here tabulated is their inconsistency. Repetition of treatment would of course lessen the

error due to random sampling, but this is difficult, due to the fact that very few orchards present sufficient uniformity of soil, topographic features and trees. That it is possible to secure definite, positive results from fertilizers where the trees are uniform individuals can be seen when we examine the R. orchard."

Such statements as these are by no means the exception in agricultural research bulletins. They may, of course, be multiplied many times.

After rather close connection with fertilizer tests for the past 16 years, wide variations of yield with individuals, or with plats under like treatment, indicate to the writer that there were initial soil differences, that the plants utilized were variable, or that unlike treatments had been given during the interim from planting to the beginning of the tests. Field experiments conducted cooperatively are quite likely to present differences due to the latter condition. In one series of fertilizer tests with the Concord grape it has taken 13 years to smooth out initial vine differences that were existant at the beginning of the experiment 16 years ago. To the eye this section had every appearance of uniformity. The fruit yields of the first year, however, indicated that one plat to the extreme west was markedly inferior to one in the middle of the vineyard, although both were receiving like fertilizers, while one plat to the extreme east was shown to be a better plat than its duplicate located near the middle of the section. In the past few years the west plat has come to the vigor and productiveness of its duplicate in the center, while the one on the extreme east has fallen in vigor and yield to that of the companion plat in the middle of the section. The reason for the high yield of the east plat was found to be the ease of access for manuring, abutting as it did on a roadway. Any weighting of plats in this test, as with most other such attempts, could only yield entirely wrong conclusions.

During the past several years we have weighed the fruit and cane growth from over 6,000 vines annually and you may be interested in knowing that the yield of fruit under like fertilizer and cultural treatment has varied from 0.4 pound per vine to 31 pounds, while the weight of pruned cane has ranged from 0.2 pound per vine to 3.1 pounds.

In the fall of 1921, an apparently uniform block of Concord grapes of about two acres was divided into 9 plats of two rows each with a buffer row between each two plats. Each row contains 34 vines. It was planned to make a quantative test of nitrate of soda with these vines, 200, 300, and 400 pounds to be used. Each plat except that receiving 400 pounds was duplicated, while four check or control plats were planned. No treatments, however, were made in 1922, except that the entire area received an application of 200 pounds of nitrate of soda and 300 pounds of acid phosphate as had been the practice for several years. In the fall of 1922, this two acre block was further divided into 27 plats of 20 vines each with the necessary buffer rows and vines between plats. Thus each plat to be treated is duplicated six times, while the checks are nine in number. Until

the present time all plats have been fertilized uniformly. These 27 plats have been assigned letters. Thus the original plat one now includes three plats, A, B, and C, as we go through the rows from south to north. Plat two now includes plats D, E, and F; plat three, G, H, and I; while plat nine to the far side of the section contains Y, Z, and Á.

During the winter of 1922–23, the weight of pruned canes from each vine from each of the 27 plats was recorded. These data show the average yield of cane from the six plats that are to receive 200 pounds of nitrate of soda per acre to be 748 pounds per acre, the average for the 300-pound plats to be 775 pounds of cane, that for the 400-pound treatment 755 pounds, while the average for the nine checks is 734 pounds per acre. While the averages for the varied treatments do not differ widely among themselves, still the range within the 6 plats that are to receive 200 pounds of nitrate of soda per acre is 143 pounds of canes, for the 300-pound plats 388 pounds, for the 400-pound plats 272 pounds of canes, while the range among the checks is 469 pounds. In other words, one check grew 469 pounds more canes per acre than another. The probable errors have been computed for the vines of each plat and a comparison has been made between the high and low yielding checks. The difference here is found to be seven times the probable error. The differences in many other comparisons are found to be several times the probable errors. In fact each group of plats gives apparently significant gains.

That the variations of cane yield between plats of this vineyard do not fluctuate widely from year to year but are fairly constant, is shown by our data taken during the winter of 1923–24. With but an occasional exception the low yielding plats of 1922 were the low yielding plats of 1923. Growing conditions were less favorable in 1923 so that relatively less growth was made. Many of the comparisons of plat yields gave increases sufficiently large to be considered significant when analyzed by the generally accepted standards.

Fruit Yields

As many fertilizer tests with fruits are planned on the row basis, the fruit records have been compared first from this standpoint. As stated before, the first division of the vineyard into plats was made on the two row basis. Thus in each two rows, are 68 vines. Plats one and seven were slated to receive 200 pounds of nitrate of soda each per acre; plats two, four, six and eight are controls or checks, plats three and nine are to receive 300 pounds of nitrate of soda, while plat five is down for 400 pounds. Computations of the probable errors of the fruit yields for the vines of each plat show that the differences are sufficiently large in the comparisons of 16 pairs of plats to be considered as due to the varied treatments had such been given. The largest difference in tonnage between two of the plats, that of plat seven which is to receive 200 pounds of nitrate of soda, and plat two, a check, is 1.05 tons per acre. The increase is in favor of the treated plat. The difference between the yields of the same two

plats in 1924 is 1.97 tons in favor of the treated. This difference was found to be significant. In 1924 comparisons of the two-row plats showed 19 pairs that differed widely enough to be considered significant. In one comparison the apparent increase from a plat booked to receive 200 pounds of nitrate of soda with another of like treatment was found to be 2.11 tons per acre. In both 1923 and 1924 practically the same variations are found for these plats.

In 1924, 14 pairs of the same plats that showed significant variations in 1923 again show significant variations. It is strongly indicated that the differences between these two-row plats are real and probably more or less permanent.

Comparison of Fruit Yields of 20-Vine Plats, 1923

The fruit from each vine of each of the 27 plats under uniform treatment was weighed at the harvest of 1923 and it was found that the minimum yield of any vine of the section was 0.7 pound, while the maximum was 16.5 pounds. These extremes were found on vines of different plats. A study of the data shows that by averaging the yields of plats of like treatment, six in number, and comparing these averages with the average for the nine checks, that but 0.06 ton separates them, while the averages of the treated plats vary among themselves by but 0.01 ton. These figures would seem to show that there was marked uniformity and that the systematic error was negligible. But the scatter of the plats and their repetition showed that the plats of like treatment varied widely. For example, one of the check plats yielded much higher than any other plat in the vineyard and in 24 of the 26 comparisons made of it with the others, the larger yield of it was found to be significant. This check yielded 0.7 ton more than the plat immediately adjacent to it. It yielded 0.75 of a ton more than the plat immediately to the east of it and 0.5 ton more per acre than the one directly to the west.

Let us suppose that without these facts in hand we had applied 200, 300, and 400 pounds of nitrate of soda per acre to the plats surrounding this check and awaited the effect. In view of past experiences, it would require several years at least for the treatments to bring about yields to equal that of the check and several more to surpass it. On the other hand, suppose that this check happened to be the one to receive a quantity of nitrate of soda, while one of the already higher yielding adjacent plats was to be the check. The inference would naturally follow that the apparent increase from the treated plat was directly attributable to the application. In either event the truth would not have been reached.

Comparisons between the yields of the 27 plats show that in 103 of the possible 526 comparisons, the differences in yield were sufficiently large to be considered significant when the probable errors were computed. In other words, 15 per cent of the plats treated uniformly suggested significance. In 33 of the comparisons, the nine control plats returned yields higher, and which were found to be significant, than the plats booked to receive nitrate of soda.

Further comparisons of the 27 plats were made by limiting them to the plats that are situated opposite to one another in the rows. The first two rows contain plats A, B, and C. The next two rows contain D, E, and F, the next two G, H, and I. Thus plats A, D, and G are opposite in the rows; and likewise plats B, E, and H; and plats C, F, and I. Plat A has thus been compared with eight plats as have plats B and C. On the basis of these comparisons it was found that the yields of 28 pairs of plats differed to the extent that the gains could be considered significant One check yielded 1.05 tons per acre more than a 200-pound nitrate of soda plat. While a 200-pound nitrate plat yielded 1.29 tons per acre more than a plat that is to receive 300 pounds of nitrate of soda. When it is considered that all plats have thus far had like treatment this is rather striking.

Comparison of the Fruit Yields of the 20-Vine Plats in 1924

Like comparisons of the yields of fruit in 1921 from the vines of the same plats, those situated as opposites, were made, and it was found that 32 pairs of plats differed so widely that the gains could be considered significant were one sure he was dealing with homogenous material. The minimum variation was found to be 0.68 ton per acre, while the maximum difference between yields was 2.5 tons. Many of the differences between adjacent plats which are to receive like and unlike treatments were well above a ton per acre. It was further found that in 10 pairs of the same plats which differed to the extent of significance in 1923, the differences were again found to be significant in 1924. In other words it is strongly indicated that 10 of the 27 plats are more vigorous and more productive even under like treatment than 10 others, and had our fertilizer applications been given without this knowledge it is entirely probable that erroneous conclusions would have been drawn, or the inconsistencies would have precluded any definite conclusions. It should be remembered that 10 plats in this experiment represent more than a third of the total number of the plats involved.

In 1924 the average yield of the six plats slated to receive 200 pounds of nitrate of soda, when compared with the averages of the six 300 and 400 pound plats, differed only by 0.1 of a ton, while the average of the nine checks was but 0.25 of a ton less than the highest yielding check plat.

What conclusions and lessons, if any, can be drawn from these comparisons that will justify the time spent in making them? It would seem that the first striking fact brought out is the probability that soil areas of any considerable extent are quite likely to lack uniformity, even though to the eye an area has every appearance of sameness. It is quite evident from these studies that the vines dealt with are exceedingly variable. Whether this is due to initial soil differences, or whether the plants when set were of different grades, is open to question. It is well known from other of our studies that heavy, well-rooted grape vines, get away to a better start than the

lighter stocks even under like soil conditions and, in consequence, this lead is maintained for many years and in some instances for the life of the planting. It may be possible that the vines of lessened vigor and productivity have been subjected to the attacks of the grape root-worm to a greater extent than those vines of higher production and heavier growth. It is also well known that the injury from this insect is irregularly distributed over a given area. The cultural care of this vineyard is known only for the past 16 years, and as it is approximately 50 years planted it is quite possible that the uneven manurial treatments of the first 30 years or more have contributed no small part to soil variability here. No doubt lack of uniformity in many other areas could be traced to a similar cause. In a section as "The Lake Erie Fruit Belt," an almost one crop area, little farm manure has been and is made. Consequently, applications of stable manure have been given irregularly. Only in exceptional instances has a vineyard of any extent been completely manured in any one season.

In any event, we are certain that in this vineyard there are vines in the plats that vary sufficiently from others to make the differences appear significant had unlike treatments been given and the data analyzed for probable errors. It is believed that knowing the constant variations in this area a method may be found whereby the necessary corrections may be made to the plats and their true values established. Annual fluctuations in yield from over or under pruning may present a difficulty with tree fruits, but with the grape the cane growth of the previous season furnishes a very satisfactory index for judging the vines' capabilities for the succeeding season.

With areas that are habitually subjected to the wash of higher lands, or those over knolls, or in fact for all those areas that include plats which are believed to lack uniformity, it would seem desirable and necessary that the true growth and fruit production values be established before different treatments are given. These data could then be given for comparison along with those obtained after the treatments have been made.

These studies clearly indicate that unless the systematic errors are known, or else they have been eliminated in the planning of the tests, it is not safe to subject the data to statistical analysis with the hope that if significance is shown correct interpretations will be forthcoming. It has been shown herein that in many of our comparisons differences were obtained from like treated plats that gave odds of over 400,000 to 1.

Frequent repetition of plats by being scattered over an area, tends to a better understanding of the systematic errors involved and as a result many of the inconsistencies become explainable.

It is evident from our tests that lack of uniformity in an area under test may in some instances be smoothed out under long continued experiments, but there are no doubt variations in soils that will not admit of such equalization even with long time tests.

It is further indicated that cooperative soil tests conducted on lands of unknown potentialities may give very unsatisfactory and

..isleading data. The writer has been in close touch with many such tests over a period of years, and in no case have the data thus secured been of any value whatsoever.

It would seem that farm soil demonstrations, with fruits at least, if they are to be of real value, should be most carefully planned with respect to soil and plant variations. While the oft-repeated suggestion to the fruit grower that he take the most promising of our data and then conduct tests under his soil conditions may lead far astray, unless his soil and individual plant variations are known. This implies that he must become an experimenter in every sense of the word.

If we assume that plant vigor does in some degree offer resistance to insect and fungous depredations and infestations, then should not systematic variations be taken into consideration in planning experiments for the control of these.

No doubt much data that have been classed as inconsistent and hence of little value would become worth-while contributions were the systematic variations known over a period of years, while it is possible that some of our conclusions already disseminated might prove unwarranted It would seem that five years is not too long a time that could be profitably spent in getting a line on the true nature of the population with which one is dealing. This period is suggested for the reason that our records over the past 16 years show that practically all extremes of climate, as drouth, excessive moisture and cold, and frost and freezing injury, have been experienced in each five year period of this span.

The drone tree or vine as well as the superlative plant is just as much a factor in field soil tests as it is in the commercial planting, perhaps more so, because we are attempting to formulate principles of far reaching application of soil management from our researches.

These studies emphasize the importance of so planning field experiments from the beginning that the data when subjected to statistical analysis can be correctly interpreted

Fruiting Habit and Pollination of Cantaloupe

By J. T. Rosa, *University Farm, Davis, Calif.*

THE Cantaloupe plant (*Cucumis melo* var. *reticulatus* (L.) *Naudin*) shows great uniformity in development and form. The plar
related varieties, including Casaba, Honey Dew and Pe
practically the same ... development. The
of a *primary stem*, ... s procum...
length of four to si
of the lower leaves
subsequent develop
the first three or f
three to five *tertiar*
feet. On these ter
secondary stems ar
which the perfect fl

In each leaf axil of the tertiary stems, as well as on the outer portic of the secondary stems and the main stem, is found a tendril, a cluster of three to five staminate flower buds, and a vegetative bud.

The staminate buds are formed very near to the growing point of the branch, generally one of them opens after the growing point has advanced five or six inches beyond. The remaining staminate buds open at intervals of one to three days thereafter, depending on temperature, and rate of plant growth. Coincident with the opening of the first staminate flower, the vegetative bud develops rapidly into a fruiting spur. In the axil of the basal leaf of the fruiting spur is borne a single flower bud that develops into a perfect blossom. This usually opens a day or two after the last of the staminate flowers in the subtending axil has closed. This fruiting spur may develop no farther after the formation of the initial perfect flower, but generally it does continue to lengthen, and forms a second perfect flower in the next leaf axil beyond. The spur may cease development here or it may continue as a vegetative branch until it reaches a length of from three to four feet. However, in no case that has been observed, is there ever more than two perfect flowers produced, and these are always in the first two leaf axils, except that sometimes the two perfect flowers are borne in the first leaf axil. In case the spur continues elongation, clusters of staminate flowers are produced in each leaf axil. Whether or not the fruiting spurs continue development as a vegetative branch seems to depend on the general vigor of the plant and the light conditions surrounding the growing point. The development of fruit does not seem to be a factor in determining the subsequent development of the spur, nor does the latter seem to affect the size or rate of development of the fruit. The length of the spurs decreases from the base of the branch toward the tips.

Fruit Setting

The fruiting spurs with their accompanying perfect flowers continue to develop as the various stems elongate, during the entire growing season. The tertiary stems may eventually have as many as 12 to 15 fruiting spurs, while the secondary stems and the main stem may each produce 25 to 30 spurs. In this way, a single plant may form as many as 300 fruiting spurs, bearing from 500 to 600 p...fect flowers. Not all of these set and mature fruit, however. ...re than 20 fruits developed on a single plant.

...eliminary breeding work ... 1923 at Davis, Cali-
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set f... ddle portion of the
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-25 variety. Ob-
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perfect flowers on the subsequent spurs recorded through the season. While most spurs produced two perfect flowers, only the first set fruit, the second withering before anthesis, though in a few cases the second perfect flower set, but did not develop if the first one had set and begun to develop. In the table only the first buds on each spur is considered since the second buds seldom set and practically never produced a fruit. As the complete data are to be published elsewhere only the summary of the results from 31 branches on 10 plants is given here.

TABLE I.

Cantaloupe Fruit Set and Developed on Different Spurs

Spur No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Number set.	14	12	9	6	4	4	4	5	7	7	10	6	9	4	4	4	2	0
Number developed	13	5	7	1	0	0	1	0	1	3	7	4	2	0	0	0	0	0
Per cent developed	42	16	22	3	0	0	3	0	3	10	22	13	7	0	0	0	0	0

Table one shows that 42 per cent of the first spurs on each branch set and developed a fruit, while only half as many set and developed on the second and third spurs. Seldom was there more than one fruit per branch in this region—if the first spur set and developed a fruit, the second and third spurs did not. If the first spur failed to set a fruit usually the second or third spur would. From the fourth to the ninth spurs the setting of fruit was slight and of the few that did set, scarcely any developed. Beginning at the ninth spur, however, there is an increase in fruit setting and in fruit development, extending over an interval of four or five spurs, though a given branch seldom develops more than a single fruit in this region Beyond the seventeenth spur no setting was observed at Davis. Under the more favorable climatic and soil conditions in the Imperial Valley and Turlock districts, however, it was noted that a third fruiting period sometimes occurred, and the interval between these periods might be shorter than above indicated. At Davis, about half the branches set one fruit on the first spur, while most of the others set one fruit on the second or third spur. This is commonly known as the "crown set" and generally constitutes the bulk of the commercial pickings. The different branches of the plant form the fruits of this crown set at very nearly the same time—during a period of not over one week. Following it is a period of two or three weeks during which few if any fruits are set, then comes a more or less indefinite period when setting may occur again, with a second period of non-setting following it, and possibly a third period of setting still later on. The second set often reach maturity during the picking season, but the third set seldom matures. While activities of the various branches of a plant are synchronized to some extent, still it seems that the individual branches function as independent units in regard to fruit setting.

Knowledge of these facts is of value to the breeders, for pollinations made on blossoms of the first spur have a considerable chance of setting, while those made later have only a slight chance. Investigations have been started to determine the internal conditions

correlated with the fruitful and non-fruitful stages, which should lead eventually to a better understanding of the regulation of cultural conditions for maximum fruit production.

Effect of Nipping Vines

Among treatments tested with a view of changing branches from the non-setting to the fruitful condition, was nipping the terminal buds from stems that bore on one of their basal spurs large early fruit. On July 23, 12 such vines were nipped. The vines chosen had open perfect flowers at the eighth spur in each case. Table II gives a summary of the performance of these nipped vines.

Table II.

Fruiting of Vines Nipped July 23

Spur number	1	2	3	4	5	6	7	8	9	10	11	12	13
Number of fruits set	—	—	—	—	4	6	5	11	9	9	4	7	3
Number developed	8	3	1	0	2	5	1	5	3	1	2	1	0

There is apparently an increased tendency toward setting and development of fruit on the later spurs, though this may not be entirely due to the effect of nipping. On branches of vigorously growing plants the effect of nipping was to increase greatly the length and vigor of the spurs near the end of the nipped vine, and in many cases these showed a much greater tendency to fruit setting than the preceding spurs. In a few cases (not included in Table II) as many as three or four well developed melons were produced near the ends of the nipped vines. While the literature does not contain much evidence in favor of the nipping of cantaloup vines, it is probable that the effects of this treatment vary with the physiological conditions prevailing within the plants. It may prove to be a valuable means of increasing the number of fruit set in the second cycle.

Pollination

The cantaloupe produces two kinds of flowers, staminate or male flowers located in clusters of three to five in the leaf axils on all parts of the plant, and monoclinous or hermaphroditic flowers located singly in the first and second axils of the short lateral branches here termed fruiting spurs. The latter flowers are referred to in the older horticultural writings as being purely pistillate, though Rane (1) drew attention to the fact that of 95 varieties tested by him, 84 had perfect flowers, while 11 had the sexes segregated into different flowers. Blin (2) also records perfect flowers for the Rocky Ford variety grown in Colorado. During 1923, 65 varieties representing all the types grown in this country, were planted at Davis and a smaller number of representative varieties were grown at Meloland, in Imperial Valley. All the varieties grown at Davis produced perfect

flowers, while at Meloland all had perfect flowers except a Peruvian melon of unknown variety. Both Rane and Blinn state that these perfect flowers are capable of self-fertilization, though only Rane records any effort to secure self-fertilized fruit. This he did by hand pollination. In the preliminary stages of cantaloupe breeding work at Davis we wished to secure a number of inbred strains through self-fertilization. It was found that all varieties were self-fertile, when emasculated perfect flowers were pollinated with pollen from staminate flowers located on the same vine. However, efforts to secure fruit from the perfect flowers without artificial pollination failed though they produce an abundance of viable pollen and the anthers dehise at the same time as in purely staminate flowers. Several methods were tried, the results of which are given in Table III

TABLE III.

Self-Polination Experiments.

(1)	Perfect flowers covered with manila paper bags 2 hours before anthesis.				
	Salmon Tint 10-25	Number buds covered	24	Number set	0
	Persian Melon	" " "	8	" "	0
	Golden Honey Dew	" " "	4	" "	0
	Honey Dew	" " "	12	" "	0
	Honey Ball	" " "	4	" "	0
	Casaba	" " "	4	" "	0
	Miscellaneous varieties	" " "	19	" "	0
(2)	Corolla lobes tied before anthesis.				
	Salmon Tint 10 25	Number buds tied	39	Number set	0
	Honey Dew	" " "	9	" "	0
	Casaba	" " "	2	" "	0
	Pink Meat	" " "	5	" "	0
(3)	Covered with cheese cloth bags.				
	Honey Dew	Number buds covered	5	Number set	0
	Casaba	" " "	2	" "	0
	Maryland Gem	" " "	11	" "	0
(4)	Whole plant covered with cheese cloth cages for six days.				
	Salmon Tint 10-25	Plant number 1	Number buds 6	Number set	0
		" " 2	" " 7	" "	0
		" " 3	" " 11	" "	0
(5)	Covered with paper bags and pollinated by hand.				
	Salmon Tint 10-25	Number buds covered	34	Number set	3
	Casaba	" " "	4	" "	1
	Honey Ball	" " "	3	" "	1

These self-pollination tests with perfect flowers were made throughout the season upon plants in all stages of development, yet no setting of fruit was secured except where hand pollination was practiced. Some of the plants in these tests were setting fruit readily on unprotected blossoms. The fact that perfect flowers enclosed in cheese-cloth cages or in small cheese-cloth sacks did not set fruit indicates that wind pollination of cantaloupes is at least not common. In nature, the insects, especially honey bees, must be chiefly responsible for pollination, either by transfer of pollen from staminate flowers to the stigmas of perfect flowers, or by transfer from the anthers of the perfect flowers to the stigmas of the same flowers. That self-pollination is not likely to occur without intervention of some outside

agency is especially well illustrated by an experiment with a young plant on which the first perfect flowers appeared July 6. Each morning for 10 days the corolla of each perfect flower that was ready to open was tied at the tip with soft twine, so that insects were excluded. None of the flowers protected in this way produced fruit, though the ovary remained green and enlarged somewhat for two days after anthesis.

Cantaloupes are visited freely by honey bees throughout the period that the flowers are open, attracted by the relatively large quantities of nectar secreted by the nectaries of these flowers. Bees working on cantaloupes exclusively are said to store a surplus of honey of good flavor. Few if any growers have taken steps to provide bees in the cantaloupe fields, yet in the light of the experimental results it seems that large numbers of bees in the field during the blooming season would insure maximum fruit-setting, at least insofar as this depends on pollination. Since the blossoms remain open for one day only, the need for plenty of pollinizers is greater.

Cantaloupe Breeding Technique

Both the perfect and staminate flowers open from 7:00 A.M. to 8:00 A.M. at Davis, California, during July. In sections having hot nights, the flowers open earlier. Beginning about 9:30 A.M. the anthers dehisc longitudinally and expose large masses of pollen. The stigma appears to be receptive from the time the flower opens in the morning until it closes in late afternoon. Both the staminate and perfect flowers have begun to close by 6:00 P.M. and by the following morning the corolla is withered.

The technique followed in the breeding work is as follows. Between 7:00 A.M. and 7:30 A.M., buds of perfect flowers that indicate by development of the yellow corolla that they will probably open that day, are emasculated by removal of the corolla which takes with it the three attached stamens. A sufficient number of staminate blossoms on the proper vines are also bagged. Between 10:00 A.M. and noon of the same morning the emasculated buds are uncovered, pollinated and re-bagged, the necessary records being written on the sack. Two days later the bags are removed and if the ovary seems to be developing, a large numbered tag is attached to the spur. For selfing of perfect flowers the buds are covered without emasculation, and at the usual pollination time the corolla is removed, one stamen detached with tweezers and the anther smeared lightly on the stigmatic lobes, which seems to be a satisfactory method of transferring pollen.

Normal fruits containing viable seed were obtained both from autogamous and geitnogamous selfing, and from the inter-varietal crosses, Salmon Tint with Honey Dew, Salmon Tint with Persian, Salmon Tint with Hoodo, and Salmon Tint with Casaba. The size, weight, and viability of the seed produced seem to vary independently of the method of pollination or of the parentage, but does show some correlation with the time of season the fruit matures. Seed of the

greatest average weight and the highest specific gravity were obtained from fruit ripening during the cooler part of the season. This is being studied further in connection with other factors affecting quality of vegetable seed.

Literature

(1) Rane, F. W. Fertilization of the Muskmelon. Proc. Soc. Prom. Agr. Sci.

(2) Blinn, P. K. Cantaloupe Breeding. Colo. Sta. Bul. 126, 1908.

Size of Seed in Tomatoes in Relation to Plant Growth and Yields

By H. D. Brown, *Purdue University, LaFayette, Ind.*

DURING the summer of 1923 Septoria leaf spot, Alternaria leaf spot and an unfavorable growing season, reduced the vitality of many tomato vines at Orleans, Indiana, to such an extent as to cause a considerable reduction in the size of the fruits. Since the Indiana Canners' Association tomato seed produced under the direction of the Purdue Agricultural Experiment Station, was to be secured from these vines it became very important to learn how the disease affected the yielding capacity of the seed.

In order to secure data on this subject frequent trips were made to Orleans during the growing season, and samples of seed were taken from the commercial run saved according to directions given in Purdue Bulletin No. 250. Seed was also saved from healthy plants as well as from plants which appeared to be suffering severely from Septoria. In 1924, yield records were secured from all lots of seed and compared with the yield records of selections made at LaFayette for the regular breeding work.

Effect of Septoria on Size of Fruit and Seed.

During the trips made in 1923, it was very evident that the badly diseased vines were producing fruits of small size and since Septoria was most in evidence, the reduced fruit size can be attributed to a large degree at least, to this disease.

Seeds from the small fruits were saved and compared with the seeds saved from large fruits. These seeds were extracted from the fruits by hand and freed from pulp by fermentation on a small scale while all the seeds saved on a commercial basis (first eight lots in Table I) were cleaned according to the commercial method described in Purdue Bulletin No. 250. Because of the difference in technique the hand saved seed would run somewhat larger than machine saved seed, as the cyclone and cylindrical dryer rub all the pubesence from the seed and in some instances almost scarify it.

In Table I, lots 578, 579, 580, and 581 show the relative size of seed saved by the hand method from large and small fruits on August 27. The percentage germination and yield increases or decreases over the calculated checks are also given. It may be noted that the seed hand saved from the large fruits were the heaviest seed of all

TABLE I.

Weight of Seed, Percentage Germination and Yield of Tomato Seed Saved at Orleans Indiana, 1923

Lot	Description	Number of Seed per gram	Per Cent Germination	Yield in Tons per Acre	Increase or Decreas over Check, Tons per Acre
572	Cml. run saved Aug. 15	395	73	9.39	—.94
573	" " " " 22	387	77	11.46	+.72
574	" " " Sept. 4	390	78	10.34	—.79
586	" " " " 10	405	—	9.97	—.46
587	" " " " 12	381	—	6.50	—3.72
588	" " " " 15	402	—	8.72	—1.29
589	" " " " 21	398	—	12.16	+1.64
596	" " fanned for sale	380	—	13.40	+1.23
594	Light seed fanned out in cleaning	608	—	9.96	—1 56
595	Small seed that fell through riddle	608	—	12.85	+1.01
590	From small fruits saved September 21	516	—	11.09	+.24
591	From large fruits saved September 21	332	—	11.65	+.47
582	From large fruits saved September 6	424	—	11.05	+.19
583	From med'm fruits saved September 6	464	—	10.08	—.48
575	From below cylindrical screen September 6	391	—	12.18	+.64
578	From largest fruit saved August 27	348	75	12.38	+.66
579	Heaviest seed from small fruits August 27	595	68	10.13	—1.38
580	Medium heavy seed from small fruits August 27	730	52	9.64	—1.66
581	Lightest seed from small fruits, August 27	880	15	10.12	—.96

the lots included in this test. The seed from the small fruits was divided into three classes according to its tendency to float in water. The lightest seed was floated off first, then the medium heavy seed and finally the heaviest seed was saved, making three lots with seed which ran 880, 730, and 595 seed per gram as compared to the seed from the large fruits which ran 348 seed per gram.

EFFECT OF SEED SIZE ON VIABILITY.

All of the above mentioned seed was germinated in sterilized soil in a flat. A glance at the germination percentages (Table I) leaves no doubt as to the value of large versus small tomato seed as there was a difference of 60 per cent between the best germinating lot (largest seed) and the poorest germinating lot (smallest seed). Lots which germinate 75–80 per cent in soil usually germinate 95 to

96 per cent when germinated between blotters in the laboratory. Germination tests of the seed saved for sale (1st 8 lots) were not completed but tests of the first three lots show this seed to be comparable to the largest seed saved by hand (lot 578). The official germination test of the seed offered for sale varied from 92 per cent to 99 per cent with only one lot less than 96 per cent. These tests which are required by law were made in the Indiana Seed Laboratory of the United States Department of Agriculture, Bureau of Plant Industry.

In connection with a study of seed size, it should be noted that there was little variation in the size of seed saved for sale from August 15 to September 21. The average number of seed per gram for these lots was 394 while the seed after being cleaned by running through a Clipper B. fanning mill averaged 380 seed per gram (lot 596). Thus the lightest seed was separated during the cleaning process. This small seed was divided into two portions, one being fanned over and the other through the riddles. Both lots of seed ran 608 per gram.

Although the seed size had not decreased to any marked extent by September 21, seed saving was stopped on that date to take all precautions possible to secure the best seed.

Although the Orleans acreage was badly infected in 1923 the acreage in the same regions in 1924 was remarkably free from the disease even to the end of the season, about the middle of October.

Seed Size and Yields

The effect of seed size on yields is much more difficult to interpret. All lots yielded over six tons per acre, indicating that the smallest of seed, if given a chance will produce a good yield.

The yield records and increases or decreases over the calculated checks are shown in the last two columns of Table I. The seed was sown in the greenhouse March 12, the plants transplanted to four inch pots May 1 and transplanted to the field June 12. They were ready to be transplanted to the field on May 20, but due to the wet, cold season it was impossible to get them out earlier. As a consequence the plants were checked slightly although by withholding water, the plants had made only a very slow, but hardened growth from May 20 to June 12. The plants were not leggy or diseased. Every tenth row in the field was a check and the check yields for each lot were calculated according to the usual practice. There were 10 plants in each lot and every lot except lot 583 had a perfect stand at the start of and throughout the season. One plant in lot 583 became infected with Mosaic and was pulled to prevent the spread to other plants. The yield of this lot was corrected to a perfect stand basis before using the data for comparison purposes.

The yield records show the customary unexplainable deviation, but it is quite apparent that the smallest seed lots, 579, 580, 581 gave reduced yields although the reduction is barely significant. With the exception of lot 587 and 595 all lots gave yields which might be anticipated from their relative seed sizes. The 32 checks over the

entire field gave a mean yield of 12.03 ±.327 tons per acre, a standard deviation of 2.74 ±2.31 and a coefficeint of variability 22.78 ± 2.02. Yield increases or decreases cannot, therefore, be considered significant unless they are greater than one ton per acre (three times .327)

Had the plants been given less care the difference in yields would no doubt have been different. The data seem to indicate that light tomato seed if given the best of care will produce a fair crop of tomatoes but slightly less than larger seed.

Effect on Septoria Infection

All lots including lots from small seed were comparatively free from Septoria until late in the season and no difference could be detected in the severeness of infection or earliness of infection in any of the lots. This of course is not to be construed as meaning that the disease may not be carried on the seed as the conditions favorable for the development of the disease were likely not provided early in the season, especially under greenhouse conditions. The observations are merely recorded in the hope that they may be of some value in confirming other observations which may be made later.

Effect of Earliness

No consistent differences could be noted between the earliness of the crop from large and small seed. It is likely that these small seeds should not be compared to immature seed and consequently the same effects known to hold true, relative to the early production of fruits, cannot be expected to follow.

Summary

Tomato fruits on diseased vines are greatly reduced in size.

The seeds produced in these small tomatoes are also much smaller than seeds produced in large fruits.

The very small seeds give lowest germination percentages and, therefore, if not separated would prove costly to the purchaser.

The seed saved by the Indiana Canners' Association is entirely freed from this small seed.

The small seeds which germinate, if carefully grown, are capable of producing a good although slightly reduced crop as compared to heavier seed.

The Nectarine as a Future Commercial Fruit in New York State

By R. Wellington, *Experiment Station, Geneva, N. Y.*

THE nectarine, or "smooth-skinned"peach, is a little known fruit in New York State. This fact was forcibly brought to our attention this past season at the New York State Fair, when nine people out of 10 who made remarks as they passed the nectarine exhibit, said:

"Look at the plums!" Why should such an old and excellent fruit be so little known? Hedrick aptly says the reason nectarines have not become an important fruit in America is that we attempt to grow European varieties and have made no serious efforts to produce varieties suitable to our soil and climatic conditions. No European peach grows successfully in America and why should it be expected that its near relative should succeed any better?

The chief objections commonly made about the nectarine are that its fruit is too small and develops an unpleasant flavor when picked green and held in storage, and also that it is particularly subject to the ravages of the curculio and brown rot. The last two objections have now been largely removed by the present day sprays. The main assets of the nectarine are its lack of "fuzz" or tomentum, attractive appearance, and delectable flavor. In fact many people who have the privilege of selecting a peach or a nectarine, usually take the latter.

Breeding Work with Nectarines

Numerous records have been published of nectarines coming from both peach and nectarine seeds and occasionally as "sports," or mutations from the peach. H. Somers Rivers of England, in his paper on "The cross-breeding of peaches and nectarines," published in the Third International Conference Report on Genetics in 1906, gave the results obtained from 35 crosses. Six crosses between peaches gave one nectarine and five peaches, 10 crosses between nectarines and peaches gave five nectarines and 13 peaches, and 11 crosses between nectarines gave 11 nectarines

The Geneva Station is carrying on breeding work with the nectarine for the obvious purpose of securing large-fruited kinds that will thrive under New York conditions. A noteworthy seedling has already been originated and named Hunter in honor of the late Mr. Henry Hunter of White Plains, New York, from whom the parental seed was obtained. The nectarine which Mr. Hunter raised grew in 1910 as a seedling under an Elberta tree* (another party less versed in varieties claimed that the tree was a Late Crawford). A sister seedling gave him a peach. Mr. Hunter sent buds and 13 fruits of the nectarine to the Geneva Station in 1914. The following spring the seed of this fruit was planted, and three seedlings were obtained, all of which produced nectarines similar in every character to their parent. The best of the lot was selected and named Hunter. This variety is described in the New York Station Bulletin No. 497 and is now being propagated and distributed by the New York State Fruit Testing Cooperative Association of Geneva, New York.

*"In all of our seedlings of Elberta, numbering some two or three thousand, we have never yet discovered a nectarine nor anything approaching the nectarine type. I would be more inclined to suspect that the nectarine secured by the individual mentioned in your lettr was from another variety, perhaps theLate Crawford noted." From a letter from Professor E. F. Palmer, Vineland Station Ontario, Canada.

Seed which has not been protected from cross-pollination was collected in 1919 from numerous nectarine varieties growing in the Station orchards, and planted the following spring. Forty-five seeds of the Advance gave three trees, one of which bore nectarines and two no fruit; 21 seeds of the Quetta (U.S. Dept. No. 34684) one nectarine and one peach; 11 seeds of the Downton, two nectarines; 45 seeds of the Early Newington, three nectarines and one tree that has not borne; 21 seeds of the Pitmaston and 17 of the River Orange, one nectarine each; and 18 seeds of the Elruge, 45 of the Humboldt and 13 of the Kentucky, no trees. Totalling these results, we have one peach and 12 nectarines. Although segregations obtained from unprotected blossoms may mean little, the results indicate that the nectarine blossoms were largely self-fertilized, providing tomentum is dominant to its absence, for the trees were surrounded by many peach varieties.

Crosses have since been made between nectarine varieties and the larger peaches such as J. H. Hale and Elberta. If Elberta or J. H. Hale carry a smooth skin factor, then nectarines should appear in the F_1 generation, but if not they will surely appear in the next generation.

This brief paper has not been prepared so much for the purpose of presenting new data on the breeding of nectarines as to urge fruit breeders and fruit growers to pay more attention to this worthy fruit. If a concentrated effort can be made to produce varieties adapted to American conditions, it should be only a matter of two or three decades before the nectarine is as well known to the consumer and as valuable a fruit to the grower as the peach.

A Test to Determine Whether Environment Has Produced Different Strains of Baldwin

By G. H. Howe, *Experiment Station, Geneva, N. Y.*

Of ALL varieties of apples now grown in the United States, Baldwin is probably more widely distributed than any other sort. Many fruit growers contend that long culture of this variety under varying soil and climatic conditions in America, has resulted in the development of several strains of Baldwins.

In order to determine whether distinct strains of this variety have originated under different environments, and if so what the value of the several strains may be, the Geneva Station purchased in 1911, 84 Baldwin apple trees from 40 different locations in the United States, involving a range of 15 states. Accompanying each set of trees the seller kindly filled out a brief questionnaire giving the history of the origin of the trees, and whether propagated from nursery stock, or from bearing trees of known behavior. Upon summing up the information furnished by 40 nurserymen, it was found that with but four or five exceptions all propagated their trees from nursery stock, some of them occasionally securing buds from both the

nursery and trees in the bearing orchard, as necessity demanded. One leading Pacific Coast nursery, long a strong advocator of "pedigreed trees", selected its buds only from bearing trees whose past behavior was fully recorded.

The Baldwin trees thus secured were planted 40 feet apart in the spring of 1911. The site of the orchard is upon a gentle slope, 120 feet above the surface of Seneca Lake and 1½ miles west of that body of water. The climate and soil are quite typical of that in central and western New York. During the past 13 years the orchard has been cared for in accordance with accepted practices. The trees have been yielding fruit in varying amounts for several years and would now be rated as being in full bearing.

Observations have been taken regularly upon the behavior of the trees, their habit of growth, and the character of the fruit produced. In not a single instance have there appeared any differences in tree growth. Each tree is similar in every respect to the average round-topped, spreading Baldwin found in every orchard in western New York Since commencing to bear fruit the trees have bloomed at the same time as other Baldwins in adjacent orchards, trees of which came from neighboring nurseries Year by year, these Baldwins from various localities in the United States have produced Baldwin apples exactly similar in size, shape, color, season, and quality to each other and to New York grown Baldwins. Careful observation and comparison of the trees and fruit for the past six years have failed to reveal a single trait which would furnish any facts upon which to base an opinion that there are different strains of the Baldwin apple due to environment. While there may be strains of the Baldwin apple in different parts of the United States, it seems fairly safe to assert that they have not originated because of differences in environment

Additional Records of Self-Sterility In Apples

By C. S Crandall, *University of Illinois, Urbana, Illinois*

SELF-STERILITY is a common attribute of the apple This is recognized by all who have made tests, but there are degrees of self-sterility There are individuals that, in some seasons, under some conditions, may be more or less self-fertile, and it is desired that trees having a tendency to self-fertility be found and made subjects of extensive tests in the effort to produce an essential in any study of character transmission—a generation of seedlings from self-pollinations.

A chief difficulty is that individuals are inconstant in exhibition of the quality of self-fertility. Because a tree shows a high degree of self fertility in one season, it is not safe to announce it as self-fertile, for in following seasons it is likely to exhibit exactly the opposite tendency. There are many illustrations of this in the records of this Station.

Success of self-pollinations must be measured by the production of seedlings having sufficient vitality to live and attain fruit production, hence, a high percentage of success in fruits matured from self-pollination is not an index of ultimate success, for fruits may be seedless, seeds may not germinate, seedlings may be so deficient in vitality that they do not live, and thus the effort in self-pollination may be an entire failure. All of these things occur with sufficient frequency to emphasize the uncertainties attending self-pollination of the apple.

Records of the apple forms tested have been handled as of the three groups—orchard varieties, crab-like forms, and hybrids, to determine whether or not there are tangible differences between the forms as thus grouped.

Orchard varieties:—Thus far 34 orchard varieties have been tested; 23 varieties failed in fruit production and to these must be added Rome Beauty and Fanny, each of which produced one seedless fruit. Six varieties, namely, Longfield, Oliver, Shackleford, Tolman, Wythe and Yellow Transparent, are represented by seedlings 1 to 11 years old, and three varieties, Akin, Oldenburg, and Roe Duchess are represented by 11 seeds produced in 1924 and not yet tested as to germination.

The total of self-pollinations on the 34 varieties is 2803, fromwhich 109 fruits on 11 varieties have matured. The indicated success percentage is 3.88. Eliminating the two seedless fruits, one from Fanny, the other from Rome Beauty, the 107 fruits from nine varieties contained 386 seeds, an average of 3 6 to each fruit. From 43 fruits of 1924, there are 120 seeds; these will have no germination record until April.

Of the 266 seeds from fruits of preceding years, 181 or 68.04 per-cent germinated. Some of the seedlings were too weak to live, and 23, or 12.71 per cent died before the time for shifting to the nursery. There were planted in the nursery 158 seedlings representing six varieties. Weak seedlings continued to die and there are now living 87, or approximately 55 per cent of the number planted in the nursery. The loss of nearly 45 per cent of the seedlings is ascribed to inherent weakness; they were seedlings that from the time of germination gave no promise of living to maturity. There are six varieties represented by seedlings, but four have only one seedling each. Only two of the 34 varieties tested give any evidence of an appreciable degree of self-fertility; these are Longfield and Wythe.

Self-pollinations on Longfield in 1917 were 48 per cent successful in fruit production; the seed average was 4.14, and the percentage of germination 54.68. Many of the seedlings were deficient in vitality and the loss during seven years has been 44.33 per cent. The 54 living seedlings grade as 20 per cent "good," 28 per cent "fair," and 52 per cent "poor." These seedlings are seven years old and some of them should begin fruiting within a year or two.

Self-pollinations on Wythe in 1915 were 12.9 per cent successful; the seed average was 5.66. Nearly 84 per cent of the seeds germinated, and the seedlings at nine years of age grade as 46 per cent

"good," 27 per cent "fair," and 27 per cent "poor." These seedlings rate better than those of Longfield and are old enough to fruit, but Wythe is tardy in every function and fruiting is likely to be further delayed.

The two varieties here considered are in line for further work in self-pollination; the other 32 varieties give very little encouragement, and with the exception of Tolman, may have no further part in the record of self-pollinations.

It is not desirable to discard Tolman, for the reason that this variety has given the only fruits harvested from self-pollinations. In 1913, self-pollination of 39 flowers of Tolman resulted in one mature fruit; this fruit contained five seeds; two seeds germinated and one seedling, exhibiting rather more vigor than is common with apple seedlings whether from self or cross pollinations, was planted in nursery, and, in the spring of 1916, given permanent place in the orchard. Growth of this seedling has been vigorous from the beginning, and, at 11 years of age, it is a symmetrical and attractive tree. In 1922, it produced four flower clusters; these were pollinated with tested Ben Davis pollen, but no fruits developed. In 1920, scions from this tree were grafted on five paradise stocks in pots for growth in the greenhouse, two of these trees flowered in February, 1923; 19 flowers on one tree and five on the other were self-pollinated. One fruit on each tree matured; the larger, described July 20, weighed 164 grams and was oblate-conical in form. Both fruits were yellow in color. These fruits were interesting as being the first produced by a seedling grown from a self-pollinated flower.

In 1924, flowers on the seedling in the orchard were more numerous; 45 were pollinated by Jonathan, yielded six mature fruits containing 45 seeds which have been planted. At the same time, 17 flowers were self-pollinated, but none of these matured fruits. The crossed fruits were described September 25; the largest weighed 144 grams, with diameters 66 mm. x 73 mm. (2.64 x 2.92 in.) and form oblate-conical; the color and appearance were the same as fruits produced in the greenhouse the preceding year.

The success attained in self-pollinations on orchard varieties is not high, but sufficient to warrant continuing the work until all varieties available have been tested as to degree of self-fertility.

Crab-like forms:— Flowers have been self-pollinated on 43 forms of this group. Of these, 16 produced no fruit; two had seedless fruit; for three the seeds failed to germinate; for two the seedlings died immediately after germination; for one the seedlings died shortly after removal to nursery. Thus, 24 of the forms must be classed as having failed. Three forms have seeds of 1924, not yet tested as to germination. This leaves 16 forms represented by living seedlings. The total of these seedlings is 98; they range in age from one to 12 years, with 87 per cent of them five or more years old and 51 per cent seven or more years old.

The older trees from self-pollinations are four or five seedlings planted in 1915 from self-pollinations made in 1912 on Malus prunifolia (838); three of these, now 12 years old, have flowered, but

only two have matured fruits. These fruits are somewhat larger than normal fruits of this form of Malus prunifolia, but otherwise quite similar.

Of the 16 forms of Malus, now represented by seedlings from self-pollinations, only two can be said to have shown any appreciable degree of self-fertility, and neither of these can rank as highly self-fertile. These two are Malus microcarpa (19644) which, from 304 flowers, self-pollinated in 1919, matured 31 fruits, or 10.19 per cent of the pollinations successful in fruit production. The 31 fruits contained 71 seeds, or 2.29 to each fruit. Over 70 per cent of the seeds germinated and 44 seedlings were transferred to the nursery.

At five years of age, there are 33 seedlings living; the loss since germination is 34 per cent. Living seedlings grade as 23 "good," six "fair," and four "poor." It is probable that all but those graded as "poor" will reach fruiting age.

The other form is Malus prunifolia var. (19651). This form gave 113 fruits from 566 self-pollinations in 1917, or 19.96 per cent of the pollinations successful. The fruits contained 638 seeds, or 5.64 to each fruit, the highest seed average of any form in the group. Germination is not nearly so good as for Malus microcarpa; 176 of the 638 seeds, or 27.58 per cent germinated; the seedlings were, in general, very weak and nearly half died before time to shift to the nursery. Of the 114 seedlings planted in the nursery, 28 are now living at seven years of age; they grade as 13 "good," 9 "fair," and 6 "poor," most of those in the two better groups should reach fruiting.

Bringing together all crab forms as a unit, it appears that 9328 flowers on 43 forms have been self-pollinated and that 855 fruits matured; this is a success percentage of 9.16, which is low, but still twice the percentage obtained for the 34 orchard varieties. Seed content was 2.66 to each fruit as compared with 3.55 to each fruit of the orchard varieties. Seedlings were of low vitality and the losses reached nearly 77 per cent, while similar losses for seedlings of orchard varieties have been about 54 per cent. As to present conditions of seedlings, the crab group makes the better showing, for, of 98 seedlings, 49 per cent grade as good, while for seedlings of the orchard variety group, only 31 per cent are in the better group.

The hybrid group includes all self-pollinations made on seedlings from controlled pollinations. The number of tests made to date is 408. The plants represent 61 different combinations of parents.

Some of these hydrids have been tested in several consecutive years and have given very diverse results. Some appear to be consistently self-sterile, as for example, Tolman X Malus atrosanguinea, which has been self-pollinated five times in the greenhouse and three times in the orchard in five different years, with a total of 417 flowers self-pollinated, all of which failed.

Of the 61 hybrids, 24 failed entirely; three bore fruits with seeds which did not germinate; one germinated one seed, but the seedling lived only a few days. Thus, 31 of the hybrids drop out until further tests are made.

Of the 30 hybrids remaining, 13 are represented by 34 seedlings one to six years old, and 17 are represented by 1213 seeds produced in 1924 and not yet tested as to germination.

While only six per cent of the self-pollinations on hybrids in 1924 yielded fruits, some trees gave relatively high percentages; a hybrid between Summer Pound Royal and Malus floribunda, from 240 self-pollinations gave 130 fruits or 54.16 per cent of the pollinations successful. The total of seeds was 483 or 3.71 to each fruit. Another hybrid, Willow X Malus floribunda, from 188 flowers gave 48 fruits or 25.53 per cent successful; these yielded 100 seeds, or 2.08 to each fruit.

On the 61 hybrids, 10,488 flowers were self-pollinated and 522 fruits matured, a success percentage of 4.97. The seed average is 2.65 to each fruit. Nearly 59 per cent of seeds planted germinated. Approximately one-third of the seedlings are now living at ages from one to six years. They grade as seven or 21 per cent "good," 16 or 47 per cent "fair," and 11 or 32 per cent "poor."

The total of work done thus far is 397 tests on 148 forms of Malus; these involved 22,619 self-pollinations, from which 1486 fruits matured. These fruits represent 6½ per cent of the self-pollinations.

The fruits contained 4054 seeds, an average of 2.72 to each fruit. Disregarding the 1214 seeds produced in 1924, which have no germination record, there have been planted 2840 seeds of which 703, or 24.75 per cent germinated. Of the 703 seedlings, 219 are now living. This is a loss of nearly 69 per cent. The seedlings vary in age from one to 12 years and rate as 85 or 39 per cent "good," 63 or 29 per cent "fair," and 71 or 32 per cent "poor."

Four seedlings grown from fruits resulting from self-pollinations have borne fruit. These are—a seedling from a fruit of Tolman self-pollinated in 1913; two seedlings from fruits of Malus prunifolia (838), self-pollinated in 1912, and one seedling from fruit of Malus floribunda self-pollinated in 1917.

This is a small showing, but it is, at least, a start, and with 85 selfed seedlings grading as "good" and half of them seven or more years old, there is prospect of early additions to the list of those fruited.

While the whole project of self-fertilizing apple flowers is attended with many failures, disappointments and discouragements, I am still of the opinion that it is worth the effort, and the present policy of making self-pollinations as they can be worked in with other branches of the breeding work is likely to be continued.

Pollen Abortion in the Peach

By H. E. Knowlton, *West Virginia University, Morgantown, W. Va.*

THERE have been but few instances of self-sterility noted in the peach. Fletcher (1) found that the variety Susquehanna was partially self-sterile and Connors (2) reported the J. H. Hale to be almost completely self-sterile due to lack of pollen production. In the following crosses he found these percentages of seedlings bearing

sterile anthers: Belle self-pollinated, 5.7 per cent; Elberta self-pollinated, 7.5 per cent; Elberta x Belle 2.2, per cent; Elberta x Greensboro, 2.7 per cent; Belle x Greensboro, 1.5 per cent. His article does not state, however, whether or not there is an entire absence of pollen in these seedlings. It would seem, therefore, that self-sterility in the peach has not been found sufficiently widespread and complete to be of economic importance except with the Hale.

The condition existing in J. H. Hale, however, led to a study of pollen abortion in several varieties in 1923 and 1924. The J. H. Hale in 1923 and 1924 failed to develop any normal pollen. In 1923, some anthers of Late Crawford at dehiscence contained a few scattered pollen grains while others contained none. No observations were made in 1924. In Rochester, Elberta and Belle, probably 5 to 10 per cent aborted in 1923, not a sufficient number to be of practical importance. This condition existing in Late Crawford was unexpected as it has not been reported before. It may partially explain why this variety bears lightly. The above observations were limited to four trees of each variety growing in our Station orchard. More extended observations will be made this year.

The time and stage of development at which abortion occurred were also studied. By March 28, 1923, almost all pollen had aborted in J. H. Hale. In the season of 1923–24, collections were started in December to make sure that all stages in the degeneration be studied. Many buds taken at this time showed decided shrinkage of the cytoplasm of the pollen mother cells probably due to poor fixation. By January 1, irregularities in many of the tetraspores were noticeable. After liberation abortion in the young microspores was much more frequent and continued until the anthers dehisced. Dorsey (3) with the plum, and Valleau (4) with the strawberry, found very similar conditions except that no breakdown occurred in the tetrad. When the flowers open, as noted by Connors, the anthers are pale in color and contain a shrunken mass of brokendown tissue with no semblance to normal pollen grains. This outward appearance of the anthers held for Late Crawford as well as for J. H. Hale. Normally microspores should undergo rapid growth and wall-thickening after liberation from the tetrad. The nuclei also divide shortly into generative and vegetative nuclei. In contrast the young pollen grains of J. H. Hale increase very little in size, their walls thicken only slightly and no divisions occur. A more complete description of the various stages in this breakdown will be given in a subsequent paper.

Even though self-sterility in J. H. Hale has been reported from all sections of the country, the question arises as to whether or not it can be modified by nutrition. In July, 1923, five pounds of nitrate of soda were applied to one J. H. Hale tree and eight pounds of acid phosphate to another. Beginning in December, buds were collected from these trees and from a check tree and sections examined using the usual cytological technique. As far as could be determined the treatments had no effect on pollen abortion. This is evidence that we are dealing with an inherent morphological type of sterility.

The J. H. Hale peach has been widely planted and it is regrettable that it should have this serious fault. Because of its large size, handsome appearance and remarkable ability to stand up under shipment, it will continue to be set out, but properly interplanted with other varieties. Contrary to Hedrick (5) it is not as hardy in the bud as the Elberta at the West Virginia Station, but is handsomer and outsells it on markets where it is known.

It might be well to state at this time, in view of its importance to the peach breeder, that the haploid number of chromosomes in the peach is eight. They are oval in shape. This conclusion is drawn from numerous counts made at the equatorial plate stage of the first reduction division of the pollen mother cells of the J. H. Hale variety. It has not been checked up with other varieties.

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An Experience with Pollenizers for Cherries

By H. B. Tukey, *Experiment Station, Geneva, N. Y.*

PRACTICALLY all of the pollination studies with cherries in America have been carried on west of the Rocky Mountains where relatively new commercial plantations of solid varietal blocks have brought the sterility question sharply to the front. The eastern fruit growing sections of America, on the other hand, have long been known for their mixed plantings of many varieties so that the pollenizer question has not been considered of major importance. In fact, the value of pollenizers has been underestimated.

Occasionally, however, one meets with solid blocks of Kieffer pears, McIntosh apples, or Lambert cherries, where new orchard enterprises have taken on the typical commercial aspect, and it is here that cross-pollination declares itself for attention. Moreover, even in those regions where the sterility problem has received fullest consideration, recommendations for the proportion of pollenizers in an orchard may vary from one in 20 to one in 9.

The Problem

Just south of the City of Hudson on the east side of the Hudson River is as fine a sweet cherry orchard as will be found in the Hudson River Valley, consisting of blocks of Windsor, Schmidt, Black Tartarian, and Lambert varieties. The trees, planted 20 feet apart each way 10 years ago, have made exceptional growth and are very uniform. The owner, Mr. F. B. Harrington, had observed in some former years that the crop from the Windsor block, 11 rows wide, was less on the east side than on the west. Along the west side, however, ran a row of Black Tartarian trees. Windsor is, of course, self-sterile, and the matter of improper pollination, therefore, immediately suggested itself.

The Investigation

The spring of 1924 afforded an excellent opportunity to study this orchard. The blooming season was extended over a period of six or seven days and the daily temperatures reached 70 degrees F. upon only two occasions. In other words, the seasonal conditions emphasized the pollination factor (1). Ten branches on one tree in each of the 11 Windsor rows were tagged, with the exception of the row adjacent to the one of Black Tartarian where three trees were used, and the number of blossoms on each of these branches were recorded on the respective tags. Later in the season after the fruit had set, a second count was made on each of the tagged branches. In this way was determined the number of flowers that had finally developed into fruit--termed "normal set." The figures under this heading in the accompanying table clearly show the *sharp* decline in normal set as the Windsor rows draw away from the one of Black Tartarian.

Table I.

Comparison of Normal Set and Hand Pollination Set in a Block of Windsor Trees, Row 1 Being Adjacent to a Row of Black Tartarian

Row	Normal Set			Hand Pollinated x Black Tartarian		
	Blossoms	Set	Per cent.	Blossoms	Set	Per cent.
1	463	201	43.4	—	—	—
2	194	52	26.7	—	—	—
3	196	45	22.9	17	6	35.2
4	293	49	16.7	43	16	37.2
5	368	76	20.6	43	18	41.8
6	154	34	22.5	52	24	46.1
7	192	45	23.3	—	—	—
8	254	25	9.8	—	—	—
9	200	29	14.5	31	12	38.7
10	—	—	—	—	—	—
11	337	77	22.8	43	18	41.8

By themselves these figures mean little, if anything, because the setting of fruit is largely dependent upon the physiological condition of the tree as influenced by a complex of external and internal factors. Fortunately, however, this point was anticipated, and before the

blossoms had opened, branches on one tree in several rows had been emasculated and the flower clusters bagged. They were later hand-pollinated with Black Tartarian pollen and rebagged, the customary methods of fruit breeding being employed throughout. The percentage of set resulting from this test is shown in the table to have remained fairly high regardless of the position of the trees in the orchard, showing that the trees were able to set fruit when properly pollinated.

But to further check these operations and to lessen the chance of tree individuality entering into consideration, the total yield of fruit on each row was secured, and the average yield per tree in pounds for each of the rows is given in Table II. It will at once be observed that the Windsor trees in the row adjacent to the one of Black Tartarian yielded over three times the amount of fruit produced by those in the seventh to eleventh rows.

TABLE II.

Comparison of Yield and Trunk Diameters in a Block of Windsor Trees. Row 1 Being Adjacent to a Row of Black Tartarian

Row	Average Trunk Diameter in Inches	Average Yield in Pounds
1	7.31	36.6
2	7.64	28.8
3	7.41	18.5
4	7.41	19.8
5	7.50	16.8
6	7.92	16.0
7	7.41	9.9
8	7.91	14.4
9	7.16	11.7
10	7.46	12.0
11	7.28	10.1

Yield by itself, however, is open to criticism as an index of tree performance on the ground that it may be seriously affected by a number of agencies of short duration such as frost and hail. Accordingly tree measurements were made, using the trunk diameters a foot above the ground for this purpose. The average trunk diameter for each row is recorded in Table II, from which it is seen that the variation between rows is not large and that it is in no way correlated with the large differences in yield.

SUMMARY AND DISCUSSION

The results are not difficult to summarize. Trunk diameter measurements show the trees in the orchard to be uniform in size and growth, yet in the season of 1924 the normal blossom-set in the first row of Windsor trees—adjacent to the Black Tartarian row—was 62 per cent more than in the second row and 127 per cent more than in the third to eleventh rows inclusive. That these differences were not due to tree individuality is shown by the fact that hand polli-

nations with Black Tartarian pollen were uniformly successful in whatever section of the orchard they were tried. Furthermore, the yield records closely parallel the normal-set records, though the rows with the larger trees are seen to carry slightly more fruit. For example, the differences between rows one and two would doubtless be even greater if the trees in row two were the same size as those in row one.

The most striking and most important observation lies in the rapidity with which the yield of fruit and the percentage set decreases as the Windsor rows become more distant from the Black Tartarian row. The decline from the first to the second row is most marked, from the second to the third row somewhat less marked, while in the remaining rows the yield and percentage of set closely approximate each other. A gradual falling off might have been expected as the distance from the pollenizers increased, but this sharp decline from the first to the second row was wholly unlooked for.

Conclusions

In drawing conclusions it is well to warn against laying undue emphasis upon these figures as representative of all seasons, though studies in New York have shown the important part played by cool, rainy weather upon the set of fruit (2). Yet they do show that in years of unfavorable weather at blooming time, *close* planting of pollenizers is of utmost importance.

Just what "close planting" should mean quickly becomes a subject for discussion. What would have been the effect of a similar row of Black Tartarian trees on the east as well as the west side of the Windsor block cannot be answered, though obviously it is impossible to assume that the present set would have been increased in like proportion from the opposite direction. In view of the sharp decline between the first and second rows it would not seem unwise to recommend that pollenizers be planted adjacent to the trees they are to pollenize. The planting of alternate rows of different varieties would be an excellent plan so far as pollination is concerned but it is seldom practicable from the standpoint of commercial fruit-growing. At all events the minimum proportion of pollenizers to realize this condition is one in nine, planted in every third space in every third row, whereby a pollenizer is placed adjacent to every standard tree—good insurance against those years when pollination is the limiting factor in fruit production.

As for pollen relations between varieties, one year's work has shown that Lambert, Bing, and Napoleon are inter-sterile just as they have been found in other sections of America (3) (4), and in addition Downer pollen failed to set fruit with Windsor. All the varieties that were tried proved self-sterile (5) (6), including Napoleon, Lambert, Bing, Windsor, Schmidt, Downer, and Black Tartarian; though with the exception of the inter-sterilities mentioned, satisfactory set was secured from all cross-pollinations, with Black Tartarian possibly the most uniformly successful.

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The Pedicels, Calyx, Sepals and Receptacles of the Flowers of the Peach are Valuable Characters for Identifying Varieties of Peaches When in Bloom and Immediately After Petal Fall

By M. A. BLAKE, *Experiment Station, New Brunswick, N. J.*

AS EARLY as 1818 John Robertson employed the flowers of the peach as one feature of a proposed system of classification of varieties. Today peach authorities recognize three flower types, the so-called large, medium and small.

This classification is based upon the width or diameter of the floral envelope at the tips of the petals. Flowers of the large type, such as those of Greensboro and Carman, are usually distinctly larger in diameter than those of Belle and Elberta of the medium type. There is not so marked a difference, however, between the so-called medium and small flower forms.

Confusion may arise, however, even in the identification of the large type when based entirely upon the diameter of the flower. The diameter of the blooms of both Carman and Elberta are given as 1¼ inches in "Peaches of New York" yet Carman has flowers that are distinctly of the large type, while Elberta flowers are of the medium type. Belle flowers are described in the same publication as 1⅜ inches in diameter which would indicate that they are larger than Carman, but as a matter of fact Belle flowers are of the medium type and are unlikely to exceed an inch in diameter as they normally expand on the tree.

DIAMETERS OF THE FLOWERS VARY

It is difficult to fix a flower diameter for any variety, especially of the medium or small type because first, the flowers upon the same tree vary in size and also upon different trees and in different seasons. Secondly, the flowers of all varieties of peaches do not expand so that the petals assume a horizontal position. The petals of many varieties maintain a semi-upright position so that the newly expand-

ed flower is saucer or cup-shaped. As they become old the petals may assume a more horizontal position especially as a result of wet weather. How then shall the diameter be established?

There are some marked differences in color between the large and medium types of bloom of the common standard varieties of peaches, but we are discussing a classification based upon the size of the flowers rather than color.

Furthermore, Prunus davidiana is characterized by flowers of the three types, but the flowers of the large form are in some cases of a smaller diameter than the medium type. Thus the old basis of classification and terminology may sometimes be misleading.

The Large Flowered Type has Broad Petals

The distinguishing feature between the large and the medium and small types of flowers is really the relative length and breadth of the petals. The so-called large flowered forms all have relatively broad petals which expand fully and assume a well spread position, forming a complete envelope about the stamens and pistil. The petals of the medium type, such as Elberta, are not only more narrow as a rule, but tend to remain partially expanded or rolled inward from the sides which intensifies the narrow effect to the eye.

The margins of the petals are actually separated from one another by a certain amount of space giving the corolla of the flower a less showy and a more divided or ragged appearance than in the case of the large type. This is particularly true of the medium and small flowers of Prunus davidiana.

Connors in 1919* called attention to the petals as a basis for differentiation between the large, medium and small types of flowers. He states that the petals of the large type range from 13 to 18 mm. wide; those of the medium type from seven to nine mm. or about one-half that of the previous type, while those of the small type range from five to six mm. wide. The range in length of the petals of the large type is given as 17 to 20 mm. of the medium type nine to 13 mm. and of the small type seven to nine mm. He states further that the petals of the small type of bloom are somewhat spatulate while those of the medium type are rather ovate.

The petals of the small type are sometimes broader in proportion to their length than in the medium, but open spaces are likely to occur between the margins of the petals when the flowers are fully expanded.

Stigmas of Medium and Small Flower Types Exposed Before the Petals Spread

Another characteristic of the flower buds of the large type is that the petals cover the stigma until the petals or flower actually expand. The stigmas of the medium and small flower type, however, often push out slightly beyond the tips of the petals before the latter start to unfold or spread.

*Proc. Amer. Soc. for Hort. Sci., p. 25.

In the case of varieties like Heath, Reeves and others of the small type the petals tend to remain in a semi-upright half spread position which makes the flower appear smaller than it really is.

The Pedicel of the Flower as a Basis for Identification

Early authorities such as Robertson and Lindley do not include pedicel, calyx or sepal characters in their classifications.

Hedrick, in "Peaches of New York"† states "Peach-flowers differ in time of appearance; in length of blooming season; they may be large, medium or small; pink, rose and rarely white; borne on pedicels of varying length, thickness, color and pubescence and both the floral and reproductive organs have modifications of their several structures." The detailed descriptive blank used for peaches at the Geneva station includes pedicels, calyx-tube and calyx-lobes, but with the exception of the color of the inside of the calyx cup these flower parts do not appear to have been regarded as characters having any special application in the classification or identification of varieties.

The pedicels of St. John are described as short, glabrous and pale green, the calyx-lobes as obtuse, glabrous within, and pubescent without.

The pedicels of Elberta are described as short, glabrous and green; calyx-lobes acute, glabrous within and pubescent without.

The pedicels of Chinese Cling are also described as short, glabrous and green and the calyx-lobes, medium to broad, obtuse, glabrous within and heavily pubescent near the outer edges.

The pedicels of Hiley are described as glabrous and greenish, the calyx-lobes as broad, obtuse, glabrous within, heavily pubescent without.

No distinction as to length is apparently noted between the pedicels of St. John, Elberta and Chinese Cling, while that of Hiley is not indicated.

Observations of Peach Pedicels at New Brunswick

During the spring of 1924, observations and measurements were made of the pedicels of a considerable number of varieties of peaches. Gray‡ defines the pedicel as "The support of a single flower" and the receptacle as "the more or less expanded or produced portion of an axis which bears the organs of a flower." In these studies, the pedicel has been regarded as the foot-stalk connecting the receptacle with the twig.

In the case of some varieties it is difficult to determine whether there is a very short pedicel or just a narrowing of the base of the receptacle. In others, however, there is a well formed pedicel marked with longitudinal lines or furrows and with a distinctive point of junction with the receptacle. All varieties observed that have marked Chinese Cling characteristics proved to have pedicels of the latter type. The varieties studied included Chinese Cling,

†Peaches of New York, p. 75.
‡Gray's Manuel of Botany, 6th Ed., p. 744.

Elberta, Belle, Hiley, Carman, Greensboro and many others. Although the forms of pedicels of the flowers of these varieties were similar there was a noticeable difference in length. Greensboro had very short pedicels, about .04 of an inch in length. Those of Chinese Cling and Elberta were somewhat longer, ranging from about .06 to .08 or .09 inches while Belle, Carman and Hiley had pedicels which averaged .08 of an inch and above in length.

A white double flowering form of the peach had pedicels that measured about .17 of an inch in length.

The flowers of Carman, Hiley and Greensboro are all of the large type and would be very difficult to distinguish one from the other, but the difference in the length of the pedicels enables one to identify Greensboro from either Carman or Hiley.

In marked contrast to the varieties just mentioned the flowers of St. John may be described as sessile or without foot-stalks or pedicels. Other varieties that proved to be sessile or very nearly so were Fitzgerald, Heath, Iron Mountain, Fox, Osprey, Crosby and Oldmixon. Varieties distinctly of the Crawford or Heath families of peaches could be readily distinguished from those of the so-called Chinese Cling by the pedicels.

The reason that fruits of such a variety as St. John appear at maturity to almost surround the twig to which they are attached is thus explained, since the receptacles are practically without foot-stalks or at least have extremely short ones.

Length of Pedicels Vary on the Same Twig

It was noted that there is some variation in the length of the pedicels of the peach on the same twig. The flowers at the tips of the twigs tended to have shorter pedicels than those at the base of the one-year-old growth or near its junction with the two-year-old wood.

The Receptacle of the Peach

When the bloom of the peach first expands it is very difficult with most varieties to determine the line of abscission between the calyx and the receptacle of the peach, but soon after the petals fall it becomes distinct since the calyx is deciduous and is shed as soon as the fruit sets and makes a little growth.

The receptacles of different varieties vary as much or more in size and form as the pedicels. Some are broad and well rounded at the base like St. John, while others are tapering so that it becomes difficult to decide whether the flowers are sessile, or have a very short pedicel, which appears as part of the elongated receptacle. Sometimes the receptacle is also distinctly lined or corrugated. In the case of Prunus davidiana it is very shallow as compared to most varieties of Prunus persica.

The Width of the Receptacle

The maximum width of the receptacle of a number of varieties of peaches was measured as soon as the petals had fallen and the abscisson line with the calyx had become distinct. Of 27 varieties

studied Motion Cling had the broadest receptacles of any with diameters of approximately .18 of an inch. Other varieties with relatively wide receptacles measuring about .16 of an inch include St. John, Slappey, Triumph, Hiley and Carman. Varieties with narrow receptacles included Sargent, Krummel, Estella and Belle. This might be expected of these varieties since the junction or union of the mature fruit with the receptacle or "stem", as it is commonly termed, is small. On the other hand, some varieties have a relatively large stem attachment to the fruit.

The Length of the Combined Receptacle and Pedicel

As soon as the abscission line of the calyx could be definitely ascertained measurements of the total length of the receptacle and pedicel were made of 28 varieties. Some marked differences in varieties were noted upon this basis. The varieties Motion Cling and Hiley were at the top of the list with a total length of receptacle and pedicel ranging from .18 to .20 of an inch. Elberta Nectarine, Belle and Carman were next in order ranging from .16 to .18 of an inch in length. Osprey, Krummel and Sargent were at the very bottom of the list with a total length of receptacle and pedicel of .10 of an inch. Again, there is noted a marked difference between Greensboro and Hiley, Belle and Carman of the Chinese Cling group. The total length of the receptacle and pedicel of Greensboro was about .12 inch, while the other varieties mentioned ranged from .16 to .18; a difference which could readily be detected.

Studies of the Calyx

Tubergen discovered a well marked correlation between the inside color of the calyx cup and the color of the flesh of the ripened fruit. Yellow-fleshed peaches develop from blossoms with orange calyx cups and white-fleshed peaches from blooms whose calyx cups are yellowish green, greenish white or cream colored. Connors has noted that some so-called white-fleshed peaches, such as Belle, have an inside calyx color that tends toward a cream or have yellowish tints, and that such white-fleshed peaches possess a factor for yellow which appears when such varieties are selfed.

Attention should be called to the fact that in employing the color of the inside of the calyx cup to determine the flesh color, well matured flowers should be selected, since some varieties which produce yellow-fleshed fruits and others which produce white have an inside calyx color that is much the same, while the flowers are in the bud stage and before the petals have expanded. These are likely to be varieties which carry factors for both white and yellow flesh.

A peach upon the station grounds with yellowish-green twigs and with an absence of red color and which produces pure white flowers and fruits of white flesh with an entire absence of red, has an inside calyx cup color of deep orange even when the petals are just ready to expand. The orange color gradually fades out as the

flowers mature, but one might easily be misled as to the flesh color of this variety in judging it from the calyx cup color of the flower in an early stage of its development.

The Form of the Calyx Tube

In "Peaches of New York" the calyx tube of different varieties is described as either obconic or campanulate in form. There is also a difference in the thickness of the walls of the calyx tube.

During May, 1924, the calyces of more than 30 varieties of peaches were cut in halves longitudinally and the width measured at the bases of the sepals. The measurements were not made until after petal fall in order to be able to note the abscission line of the calyx. The figures may not, therefore, be accurate for flowers just expanded to full bloom, but they do at least show the comparative width of the calyx tube at the point measured.

Crosby, Fox, Motion Cling, St. John and Slappey proved to have calyces which measured from .22 to .24 of an inch across, while those of Greensboro, Sargent, Fei and Estella measured about .16 of an inch in diameter. The calyces of Chinese Cling appeared to be even a bit narrower.

The Length and Width of Sepals

The calyx-lobes or sepals of the peach are described in "Peaches of New York" as to width, length and form and whether glabrous or pubescent, but have not apparently been employed specifically to set apart any variety or varieties.

Observations at New Brunswick in 1924 made immediately after petal fall, showed that some varieties tended to form sepals that were irregular as to width and not infrequently six sepals instead of five to a single flower. In such instances one or more sepals were likely to be relatively narrow.

Motion Cling had very long sepals measuring .28 of an inch in length and they were also very wide, ranging from .20 to .22 of an inch at their widest point. Carman sepals measured about .20 of an inch long and .14 to .18 inch wide. Elberta, Belle and Lippiatt Late Red also had long sepals and Dewey, Triumph and Hiley rather broad sepals.

The sepals of Sargent ranged from .08 to .10 of an inch in length, or less than one-half those of Motion Cling, Krummel, Belle and Estella, and proved to have as narrow sepals as any variety the range in width being from .08 to .10 inches.

The Calyx, Receptacle and Pedicel Compared as a Unit

One would ordinarily compare the entire calyx and support of a peach especially after petal fall, and some varieties are quite distinctive on such a basis.

Motion Cling, a peach introduced from New Zealand by the United States Foreign Seed and Plant Introduction Bureau and resembling a dwarf, clingstone form of Elberta, has an unusually

large outer perianth, receptacle and foot-stalk. Hiley has a relatively large outer perianth and base parts. On the other hand, Chinese Cling and Greensboro of this same general family, have relatively small parts.

General Terms are not Specific Enough

It is difficult for the average person to effectively use such terms as long, medium and short, broad, medium, or narrow, in attempting to identify an unknown variety by means of a published description. In fact, most of the published descriptions of varieties of fruits that closely resemble each other fail to state the character or characters by which the two varieties may be identified one from the other. I refer to such peaches, for example, as Belle and Ray. In this connection a detailed classification and key to varieties with some actual measurements as to width and length of petals and sepals, length of pedicels and width and depth of receptacles would be a marked improvement over what is at present available. The facts noted in this paper are in the nature of preliminary observations. Further studies should enable one to establish more facts about the flower characters of the peach that would prove of great assistance in identifying groups and varieties of peaches.

Factors Associated with Size of Fruit in the Black Raspberry

By Stanley Johnston, *Experiment Station, South Haven, Michigan*

This address will appear in a bulletin from the Michigan Agricultural Experiment Station.

Studies Relating to the Handling of Sweet Cherries

By Henry Hartman, *Oregon Experiment Station, Corvallis, Ore.*

WHILE considerable attention has been paid to certain phases of the sweet cherry industry, very little work has been done which bears upon handling practices. No detailed study has been made of the activities of sweet cherries during the period of ripening and decay, and it is generally admitted that under the present methods of harvesting, shipping and processing, the best of quality is seldom obtained. While the sweet cherry is potentially one of the finest of all fruits, it is only occasionally that the consumer has the opportunity of appreciating its real worth.

The present study, which is a phase of the general fruit handling problem of the Oregon Station, was undertaken in 1924, and represents the work of a single season. This paper, therefore, is merely a preliminary report.

Time of Picking in Relation to Fresh Fruit Qualities

Casual observations of the handling of the sweet cherry have emphasized the fact that the degree of maturity, which the fruit has attained when picked, exerts a pronounced influence upon its ultimate dessert quality. To gain more information on this point, the following experiment was undertaken. Representative lots of Napoleon and Lambert were gathered at intervals of two to four days. Altogether, 10 pickings of Napoleon were made, the first on June 17, and the final one on July 12. In the case of the Lambert, nine pickings were made between June 24 and July 22. Within these ranges of season, the fruit of each variety passed from a stage of comparative immaturity to one beyond the optimum picking condition. To reduce the probability of environmental differences, all the lots of each variety were taken from a single tree, and an attempt was made to select only the specimens that were of average maturity for the particular time of picking. A portion of the fruit from each lot was placed in common storage at a temperature of 66° F., and a relative humidity of 50 to 60 per cent. Tests and observations were made with the aim of ascertaining, so far as possible, the relation of time of picking to (1) firmness, (2) sugar content, (3) acid content, (4) size, (5) dessert quality, (6) keeping quality, and (7) color.

Firmness of the Fruit

The firmness of the fruit at the time of picking was determined by means of a specially constructed pressure tester, consisting chiefly of a rounded glass plunger two millimeters in diameter, and a chatilon metric spring scale. With this apparatus, it was possible to measure the resistance to pressure offered by the epidermal and cortical regions of the fruit. The figures given (Table I) represent the average of at least 100 determinations in each case.

It is apparent, from these figures, that there was a gradual decrease of resistance throughout the season. This decrease, however, was less striking than that commonly manifested by other fruits. In Napoleon, for example, the decrease in resistance for the entire period was but 17.3 per cent, this, in spite of the fact, that during this time the fruit passed from a stage of immaturity to one considerably past prime condition. During the period when the variety could really be considered marketable at all, the decrease in resistance was but 5.7 per cent. Allowing the fruit to hang a few days longer, therefore, does not materially affect firmness.

Sugar Content

The sugar content was determined by means of a Balling scale hydrometer. The figures given (Table I), therefore, cannot be taken as indicating the exact amounts of sugar present. Rather, they indicate the percentages of soluble solids in the juice. For a comparative study of sugar changes, however, they are fairly adequate.

Determinations were made upon fresh juice a few minutes after the fruit was removed from the trees. The figures given in each case represent the average of several determinations and are corrected for a temperature of 17.5°C.

Obviously, there was a consistent and rather pronounced increase in sugars during the period of maturity. The juice of Napoleon from the time of the first picking to that of the last, showed an increase in soluble solids from 12.1 to 22.4 per cent, while that of Lambert showed an increase from 11.3 to 22.2 per cent. Not only was the increase in sugars rapid at the beginning of the period, but, seemingly, it continued at a uniform rate even to the time when the fruit was past its prime.

Acid Content

The acid content was determined by titrating the fresh juice with N/10 sodium hydroxide, the acid present being calculated as malic. Fifty cubic centimeters of juice were used for each determination, and the figures given (Table I) represent the average of three determinations for each lot.

Evidently a gradual reduction of the acid took place during the ripening period, Napoleon showing a reduction from .64 to .35 per cent and Lambert from .41 to .24 per cent This reduction seems to have been consistent throughout the season.

Increase in Weight

A matter of particular interest to growers of sweet cherries is that of increase in the weight and size of the fruit during the ripening period. What sacrifice in tonnage does the grower make when he picks his cherries prematurely and what increase may be expected if the fruit is allowed to hang until fully ripe? Information on this point was obtained by weighing about 1000 specimens at the time of each picking and computing the average weight of specimens. The data obtained in this manner (Table I) show that there is a rather marked increase in size from the time cherries began maturing to the time when they are fully ripened. Napoleon, during this time, showed an increase of 30.2 per cent while Lambert showed an increase of 36.2 per cent. This gives an average daily increase of over 1.2 per cent in the case of Napoleon, and nearly 1.3 per cent in the case of Lambert. Though the greater increase took place just before the fruit reached prime condition, the specimens continued to gain weight even after full maturity was attained.

Dessert Quality

Time of picking had a marked effect on dessert quality. All the fruit of the early pickings was sour and more or less bitter in taste. That picked real late in the season was very sweet in taste, but was slightly insipid. By far the best quality for Napoleon was attained by the fruit picked between June 30 and July 6, while the best Lambert quality developed with the fruit picked between July 14

and 19. Most of the commercial crop of these varieties in Western Oregon, whether for fresh consumption, canning or drying, was gathered long before these dates. The juice of both Napoleon and Lambert became richer and more syrupy in nature as the season progressed.

Observations of the fruit placed in storage gave no indication that sweet cherries ever improve in quality after picking. The reverse of this, in fact, appeared to be true. In the case of the early picked fruit, acidity and bitterness seem to become more pronounced and in no case was there an apparent increase in sweetness.

Shipping Quality

Time of picking does not seem to affect materially the shipping quality of sweet cherries. Cherries picked when fully matured apparently held up as well as did the ones picked while comparatively green. They did not shrivel so badly and they displayed less discoloration due to oxidase activity. Bruises and decay organisms appear to have more influence upon the shipping qualities of sweet cherries than time of picking.

Tests of Maturity

When left to their discretion, growers have generally determined the time of picking sweet cherries by the aid of such factors as sweetness, size and color. Obviously, these are capable of various interpretations, with the result that controversies arise and the sweet cherry crop is harvested at widely varying stages of maturity. Doubtless there is need for a test of maturity that indicates rather definitely the degree of ripeness, that excludes the human element so far as possible, and that can be easily and quickly applied.

The Pressure Test

The pressure test as an indicator of maturity in the sweet cherry did not meet with any degree of success. It is true, as already indicated, that sweet cherries manifest a gradual decrease in resistance during the ripening season, but this apparently is not sufficiently indicative to be a guide of time of picking.

Specific Gravity Test

As already shown, there is a rather marked and consistent increase in sugars and other soluable solids during the ripening period of sweet cherries, and a test of maturity based upon the specific gravity of the juice seems very feasible at this time. The work of several seasons, however, will be necessary before definite recommendations can be made.

Time of Picking in Relation to Canning Qualities

To gain information concerning the relation of time of picking to canning qualities, Napoleon and Lambert cherries were picked and canned at intervals during the season. Altogether, eight sepa-

rate pickings of Napoleon were made between June 17 and July 6. (Table II). Three pickings of Lambert were made on July 4, 11, and 20, respectively. Fruit from each picking was processed in accordance with the accepted commercial canning practices. In the case of Napoleon, six cans of each picking were processed in 40 per cent syrup while a like number were processed in water The fruits from the Lambert pickings were canned in 40 per cent syrup only. Each lot was cooked for 11½ minutes in the Anderson-Barngrover rotary cooker and was given an exhaust of 8½ minutes in water at a temperature of 190° F. Common No. 2 tin cans were used. Observations of the canned product were made about five months later.

Changes in Concentration of the Syrup

The canning trade for many years has been aware of the fact that dilution of the syrup occurs whenever the sugar content of the fruit itself is lower than that of the syrup in which it is canned. This is in accordance with the well known facts of osmosis. Since cherries picked at different times contain different amounts of sugar (Table I), it is to be expected that time of picking would have bearing upon the amount of dilution Table II gives the hydrometer readings of the syrup of each lot of Napoleon and also the amount of dilution in percentages.

Obviously, the cherries of the early pickings show a much greater dilution than those picked later in the season. The dilution of the first lot of Napoleon, for example, is 43 7 per cent while that of the last lot is but 21.2 per cent. Cherries canned when thoroughly ripe, therefore, require considerably less sugar to pass the trade requirements so far as concentration of syrup is concerned.

Firmness of the Product

Firmness is one of the requisites of well canned fruit Commercial canners, in fact, frequently reduce the length of cook and take a chance on keeping quality in order to secure firmness. During these experiments some interesting facts came to light (Table II) concerning the relationship of time of picking to the firmness of the canned product. The pressure tester already described again furnished the data. A large number of determinations were made in each case, and while rather wide variations were recorded between individual readings, the average figures obtained are fairly uniform.

It will be noted (Table II) that the firmness of the first lot of Napeleon as indicated in grams, is 63 1, while that of the last lot is 94.4. The riper cherries, in other words, gave a much firmer product than did the fruit that was comparatively immature. The difference in all cases was sufficent to be noticeable by casual observation.

Volume Changes

When processed in high degree syrup, fruits usually undergo a certain amount of shrinkage. This is due to the fact that a certain percentage of the juice of the fruit is given up to the syrup by os-

TABLE I

Effect of Time of Picking on the Fresh Fruit Qualties of Napoleon Cherries

Lot No.	Date of Picking	Pressure Test (grams)	Sugar in Juice Per cent	Acid in juice (Calculated as Malic) Per cent	Average Weight of specimens	Increase in Weight Per cent	Condition at Picking Time
1	June 17	295.0	12.1	.636	4.89		Undercolored for the variety. Undersized. Sour and more or less bitter in taste. Tendency to show bruises
2	June 19	272.1	13.2	.596	4.92	.6	Same as June 17 above.
3	June 21	274.2	14.2	.572	5.12	4.7	Considerably richer in color. More or less undersized. Still more or less sour and bitter, but much better in quality. Tendency to show bruises less evident.
4	June 24	260.8	15.3	.549	5.98	22.3	Fairly good color for the variety. Much larger in size. Fair in quality, but still lacking in sweetness.
5	June 26	251.0	15.5	.536	6.04	23.5	Good color for the variety. Still slightly undersized. Fair in quality, but still lacking somewhat in sweetness.
6	June 30	266.4	18.9	.510	6.27	26.9	Good color for the variety. Apparently full sized. Sweet and of good quality.
7	July 3	249.4	19.6	.509	6.28	26.9	High in color. Apparently full sized. Full quality for the variety.
8	July 6	261.2	20.9	.508	6.36	30.0	High in color. Apparently full sized. Full quality for the variety. Slight indication of shriveling.
9	July 9	255.0	22.4	.442	6.37	30.2	High in color. Apparently full sized. Very sweet but slightly insipid. Some indication of shriveling. Scald present on some specimens. Evidently past prime condition.
10	July 12	243.8	22.3	.348	6.37	30.2	High in color. Apparently full sized. Very sweet but insipid. Some indication of shriveling. Scald present on some specimens. Evidently past prime condition.

TABLE II

Effect of Time of Picking on the Canning Qualities of Napoleon Cherries. (Canned in 40 per cent syrup)

Lot No.	Date of Picking and Canning	Sugar in Syrup after Canning Per cent	Dilution of Syrup Per cent	Firmness of fruit after Canning grams	Condition of Fruit After Canning
1	June 17	22.5	43.7	63.1	Small in size. More or less shriveled. Soft in texture. Flat in taste and but slightly aromatic. Pale in color. Juice light in color. Considerable discoloration at stem ends.
2	June 29	24.7	38.2	61.9	Same as on June 17 above.
3	June 21	25.1	37.2	73.0	Larger in size. Less shriveling. Somewhat firmer in texture. Better in taste with stronger aroma. Richer in color. Juice light in color. Slight discoloration at stem ends.
4	June 24	24.7	38.2	82.2	Fairly large in size. Less shriveling. Fairly firm in texture. Better in taste with stronger aroma. Good golden color. Juice light in color. Practically no discoloration at stem ends.
5	June 26	26.2	34.5	83.1	Large in size. Practically no shriveling. Firmer in texture. Fairly good flavor with stronger aroma. Good golden color. Juice light in color. No discoloration at stem ends.
6	June 30	27.6	32.2	90.5	Large in size. Practically no shriveling. Firm in texture. Good cherry flavor, with strong aroma. Good golden color. Juice light in color. No discoloration at stem ends.
7	July 3	28.4	29.0	91.4	Full sized. Practically no shriveling. Very firm in texture. Strong cherry flavor and aroma. Some discoloration evident. Juice slightly darker in color. No discoloration at stem ends.
8	July 6	31.5	21.2	94.4	Full sized. Practically no shriveling. Very firm in texture. Strong cherry flavor and aroma. Considerable discoloration Juice darker in color No discoloration at stem ends

mosis. As might be expected, the greater loss in volume occurs in the case of fruit with a low sugar content. Fruit canned early in the season, therefore, may be expected to show more shrinkage than that canned when fully ripe. The difference in the amount of shrinkage between fruit canned at various stages of maturity was determined by measuring the volume of Lambert cherries before and after processing. This was accomplished by immersing the cherries in water and computing the amount of displacement.

Table III gives the data obtained in this test. Obviously, time of picking may have considerable influence upon the amount of shrinkage taking place during the canning process. As the figures indicate, the cherries picked and canned on July 4 show a loss in volume of 17.1 per cent, while those canned on July 20 show a loss of 9.8 per cent.

TABLE III

Effect of Time of Picking on the Volume of Canned Lambert Cherries

Lot number	Date of Picking and Canning	Volume of Fruit before Canning c. c.	Volume of Fruit after Canning c. c.	Loss of Volume. Per cent
1	7/4	1042	865	17.1
2	7/11	1085	931	14.0
3	7/20	1060	955	9.8

QUALITY AND APPEARANCE

A considerable difference in the quality and appearance of the canned product was evident between the fruit of the various pickings. The early picked cherries, in general, gave a product that was small in size, more or less flat in taste, soft in texture, and that displayed considerable shriveling. Those canned when fully matured had a livlier appearance, were larger in size, firmer in texture, more aromatic, and had a more pronounced cherry flavor. Those picked and canned when past their prime were of good quality and texture, but showed a certain amount of discoloration that might be objectionable to the trade.

A Chlorotic Condition of Pear Trees

By A. H. HENDRICKSON, *University of California, Berkeley, Calif.*

IN THE lower end of the Santa Clara Valley in California there is a considerable area of soil classified by the Bureau of Soils of the United States Department of Agriculture, as Dublin adobe which is underlain at varying depths with a whitish sub-soil of high calcium content. The depth at which this calcareous sub-soil is found varies from 14 inches to five or six feet or more. The above district lies from three to 10 or 12 miles from the southern end of San Francisco Bay, and is but a few feet above high tide. Formerly the water table was within a few feet of the surface, and most of the area was often covered with water for several months during the winter season. Of late years there has been a decided lowering of the water table, due to the large number of deep well pumps which have been installed to furnish irrigation water With the lowering of the water table the tree roots grew downward into the calcareous layer. Evidence of chlorosis soon developed. This chlorotic condition is now more or less pronounced over an area of several hundred acres of mature pear orchards.

The foliage of the chlorotic trees is bright lemon yellow in color, in some cases becoming nearly white toward the end of the growing season. The new growth is short and sickly in appearance. Fruit production ceases entirely in the worst cases. With some varieties of pears the leaves formed early in the spring are green and apparently normal, but those appearing later in the season are distinctly yellow. The yellow leaves tend to drop early in the season.

The use of iron sulphate for the treatment of this type of chlorosis has long been known In the United States Gile (1) has reported his results obtained by the use of iron sulphate on pineapples. More recently Korstian and others (2) report the successful treatment of chlorotic coniferous seedlings by spraying with a one per cent solution of iron sulphate.

In France, Arnaud (3) injected iron sulphate and olive oil into the trunk and large branches of a chlorotic pear tree. The leaves turned green in eight days and remained so for four years. Other accounts of the use of injections of solutions or salts occur in the literature in connection with chlorosis and other diseases.

This paper deals with some of the horticultural phases of the chlorosis problem and gives the results obtained by certain treatments. The results of chemical studies of leaves, branches and roots of both chlorotic and normal trees will be given in another paper.

In April, 1921, several large chlorotic trees were sprayed with one per cent, two per cent and five per cent solutions of iron sulphate. The five per cent solution caused severe burning of the foliage. The weaker solutions were safe, but were not satisfactory for other reasons. The material did not cover the foliage evenly and the result was a speckled appearance of the leaves. The leaves turned

green wherever covered by the spray, but there seemed to be little if any lateral movement of the iron as the green areas remained unchanged in size throughout the season. Several sprayings were necessary each season, in order to cover the new leaves as they were formed.

In June of the same year, holes were bored in the trunks and main branches of several trees with a quarter-inch augur. Different iron compounds were placed in these holes. A small amount was picked up on the point of a knife and placed just inside of the cambium in the sap wood. Ferric phosphate, ferric oxide, and ferrous sulphate, were used in this way. Only the latter showed any effect. By means of ferrous sulphate inserted as descr bed above it was possible to change whole trees or parts of trees from an extremely chlorotic condition to normal color. This change usually took place in two or three weeks after the treatment. The treated branches bore normal green foliage the two following seasons, but during the third year after treatment slight chlorosis was again apparent.

There seemed to be but little lateral movement of the salt within the tree. If the iron sulphate were placed in a hole in the trunk directly beneath one main scaffold branch, that branch turned green while the others remained chlorotic. One branch each of several carefully chosen pairs of branches was treated with iron sulphate. The hole was made about an inch above the crotch or fork in one of the branches. The treated branch of the pair turned green, while the untreated one remained yellow showing there was no movement of the salt to the second member of the pair. Dipping the freshly cut ends of shoots in early spring in a two per cent solution of iron sulphate also caused all of the leaves formed on those shoots that season to be green while the nearby branches remained yellow. The amount of new growth on the treated branches was strikingly increased. These observations are in keeping with the work of Auchter (4).

Several dangers attended the use of ferrous sulphate in this manner. If too much material was inserted in the boring, all the leaves above it turned black as if affected with pear blight, and fell off. Sometimes considerable areas of the bark were killed. Likewise, if some of the iron sulphate was spilled on the cambium a considerable area of the bark beneath the hole was quickly killed.

Another experiment started in June, 1921, consisted in inserting a tube, which was connected to a reservoir of iron sulphate solution suspended above, into one of the main scaffold branches. Solutions up to one-tenth of one per cent seemed to be fairly safe, but, when the strength of the solution was increased to one per cent or more, the treated branches were killed. As the experiments were chiefly designed to provide a method by which the grower could treat his own trees, the introduction of either crystals or solution into holes in the tree was not advised, being somewhat dangerous in unskilled hands. This method would undoubtedly provide the easiest way of treating trees affected by this type of chlorosis if it could be made sufficiently safe. Further studies on this phase of the problem are under way.

PLATE III. Typical young chlorotic Bartlett pear tree, Photographed Aug. 20, 1921

PLATE IV. Young Bartlett pear tree treated with 2 pounds of Iron sulphate applied next to the roots, May 19, 1921. Photographed Aug. 20, 1921.

The safest method of treatment for the grower to use seemed to be the application of the crystals of iron sulphate directly on and around the roots. The application of as much as 20 pounds per 15 year old tree when scattered on the surface of the soil showed absolutely no effects. Chlorotic raspberry plants showed no effect when crystals were scattered on the surface of the soil close to the row. However, when the crystals were applied in trenches close to the roots, the effects were positive and rapid. For pear trees 12 to 15 years old with a trunk about six or eight inches in diameter, from 15 to 20 pounds applied in trenches next to the roots gave the best results. The application of the crystals in holes made with ordinary soil augurs was also satisfactory. Both fall and early spring applications were effective for the following growing season, but when applied as late as June only a little change in the color of the foliage was observed. Ordinarily the results were best when the crystals were moistened with a pail or two of water before the trench was closed.

The effects of a single treatment ordinarily lasted from two to three years. At the end of that time another application appears to be necessary. Ordinarily the second year after treatment trees which had been unfruitful began to produce some fruit. Instances were repeatedly observed where single treated branches bore normal crops of fruit while other branches on the same tree which had not been treated were entirely barren.

Other instances of the effect of injecting barren trees with iron sulphate and other nutritive salts in stimulating growth and fruitfulness are on record. Taboury (5) injected $FeSO_4$ and $NaNO_3$ solutions into an old sterile pear tree with beneficial effects on leaf size and fruiting. Calvino (6) injected large quantities (50 liters) of solution containing superphosphate, K_2SO_4, $NaNO_3$ and $FeSO_4$ into a sterile pear tree apparently inducing fruiting thereby. Mokrjetsky, quoted by Rumbold, C.(7), found beneficial effects induced by the injection of iron sulphate into fruit trees in Russia.

The rootstocks upon which the pear trees were grown also influenced the amount of chlorosis. The Japanese pear (Pyrus serotina) and the quince used for dwarf stock, seem to be more subject to this disorder than the French pear stock (Pyrus communis). Most varieties of pears grown on this type of soil show more or less chlorosis. Among those which show the most are Bartlett, Comice, P. Barry, Nelis, Glout Morceau, while the Hardy and Clairgeau seem to be comparatively resistant to this trouble. Other plants which show chlorosis when grown on this type of soil are: apple (P. malus), plum (P. domestica), English walnut (J. regia), and raspberries and blackberries (Rubus sp.)

Plates III and IV show in a striking manner the results obtained with ferrous sulphate. Two trees as nearly the same size as possible and both showing approximately the same amount of chlorosis were chosen. One was treated with two pounds of ferrous sulphate applied next to the roots and moistened with a pail of water on May 19. The photographs were taken on August 30. The check tree was entirely yellow and had lost most of its leaves, while

the treated tree was normal green in color and had made from 12 to 30 inches of new growth. The photograph of the check tree was taken with a K-3 filter on a panchromatic plate to show the yellow color.

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Water Absorption of Pear Wood*

By A. K. Ghamrawy, *University of California, Berkeley, Calif.*

THAT the deciduous tree is in an unsaturated condition with respect to water during the season when leaves are present, is well known. The transpiration stream is said to be under tension at this time due to the rapid loss of water through the leaves and the resistance to absorption presented by the roots. On the other hand, there seems to have been little investigation of the conditions in which the water content of the tree exists during the dormant season. Slow transpiration is known to go on during this season, and consequently some absorption must occur. The water content has been noted to increase somewhat, particularly during the last part of the winter. In some cases, at a certain time of the year when the growing season starts and before the opening of the buds, there exists a so-called positive sap pressure which results in bleeding through any injury. Most trees do not show the bleeding phenomenon and among these are the common fruit trees. It is the purpose of this paper to report some experiments which show something of the condition existing in the pear tree with regard to water content during the dormant season.

*This work was done in the laboratory of Dr. J. P. Bennett of the University of California. I wish to express my gratitude to Dr. Bennett for valuable suggestions and a sympathetic interest in my work.

The apparatus used in these experiments was a specially devised manometer composed of a U tube of 6 mm. diameter tubing, the shorter arm of which was about 35 cms. long, with the longer arm inserted in a two-holed rubber stopper. This stopper fitted into the wide portion of a Gooch funnel which was closed at the small end with a piece of rubber tubing and a pinch-cock. It was filled with water and mercury and attached to the stub of a severed branch in November and at intervals later. Water was absorbed against an increasing back pressure of mercury. The rate of water absorption indicated the degree of saturation as well as the negative tension created by transpiration from the leaves or bark. The rate of absorption depended partly upon the moisture content of the tissue and partly upon transpiration In the case of a positive sap pressure, a rise of mercury in the opposite direction would be expected.

The experiments covered a period of six months, from November 13, 1923, to May 20, 1924 This period covered three stages of the life of the tree, namely, the autumn before the leaf-fall, the dormant season after the leaf-fall, and the resumption of growth. Moisture determinations of twigs were taken in the meantime at fortnightly intervals Both these and the rate of mercury rise for a representative tree are given below.

Mercury Rise		Moisture Determinations	
Date	Rise in cms in 30 mins	Date	Per cent of moisture
November 13—Before leaf fall	27.5	October 27	50.29
January 15—Dormant season	17.3	January 17	51.72
January 23— " "	11	January 23	51.80
January 29— " "	6.2	January 28	52.90
February 13— " "	6.0	February 9	53.60
March 1— " "	7.5	February 23	54.51
March 6— " "	10.0	February 26	54.86
March 27— " "	6	March 14	54.26
April 5— " "	8.2	March 29	56.36
April 12— " "	4.5	April 12	60.05
April 23—Growth resumed	39.5	May 19	61.94
May 17 " "	16.8	June 3	62.30

It seems from the above data that pear trees fell to the lowest point in moisture content sometime before November 27 and after June 3, probably in late summer After the leaf-fall, however, the evaporation was limited to the twig and branch surfaces and absorption of water in excess of the loss went on through the dormant roots. As a result, a gradual rise in moisture content occurred and at the same time a falling off of the rate of absorption from the attached manometer.

As the new rootlets started to grow toward the middle of February, while the rate of evaporation from the unchanged twig surface remained more or less constant, the rate of absorption became a little more rapid until the middle of March when a sharp rise in water content occurred. This is perhaps accounted for by the rapid formation of the new rootlets and the abundant soil moisture so that

the water absorbed considerably exceeded the loss due to the evaporation from the bark surfaces. This sharp rise in moisture content continued during March and April. Afterward came the stage when the leaves developed rapidly and evaporation increased, but not in excess of the absorptive capacity of the roots. The rise in moisture content of the branches continued at a lessened rate until June 3 when the experiments were discontinued. After the resumption of growth, the rise in moisture was due to the formation of new tissues as well as to the actual rise in the water content of the wood itself.

From November 13, the rise in moisture was more or less inversely proportional to the reduction in water absorbing capacity of the branches until the second half of April, when the absorption suddenly rose to its maximum in spite of the fact that the moisture had just made a rapid increase and was still rising. In other words, at that particular time the relation that had previously existed between water content of tissues and absorption rate was reversed.

In the period immediately after November 13, the pear trees started to shed their leaves until by the first of January they became completely bare. Thus the chief evaporating surface was eliminated at that time. The water absorbing capacity likewise decreased and continued at the low rate indicated till April 15. The gradual increase in moisture content agrees with this fact. In the latter half of April, the leaves vigorously developed and with the transpiring capacity they had then, created a high negative tension in the tree, irrespective of the moisture content

As a conclusion from the above study, it appeared that pear trees under experiment did not have a positive sap pressure at any time, but were continuously unsaturated as indicated by the capacity to absorb water in the dormant season.

Parallel with the above study, a laboratory investigation was carried out in which the absorption capacity of living and dead one-year old twigs was tested.

It was found that the rate of absorption of the wood mainly depended upon the rate of evaporation from the twig. A difference of about 17 cms. in mercury rise in four days between twigs protected by waxing the surface and unprotected twigs substantiates this fact. Such a reduction in the absorption was also brought about by covering and protecting the trees from evaporation and at the same time irrigating them.

Aside from the effect of evaporation, however, the wood appeared to have a considerable capacity for water absorption. Thus twigs weighing about 30 gms. and measuring about 40 cms. in length, effectively protected from evaporation, absorbed moisture causing a total rise in the mercury of six cms. in four days. This amount of absorption apparently wholly depended upon the water deficit in the twig; for branches saturated by previous soaking in water for three days did not absorb at all.

Moreover, the amount of absorption did not appear to depend upon the influence of the living cells of the branch, for branches killed by being subjected to steam for one hour and protected against

evaporation, absorbed considerably more moisture than the living ones. The absorption of water by the dead twigs appeared to be due entirely to imbibition, which, favored in the dormant season by the lack of evaporation from the leaves and the ample moisture in the soil, might be responsible for the filling of the trees with water during the dormant season.

Living twigs would be expected to absorb more than dead ones since osmotic action by the living cells would be present in addition to imbibition of unsaturated walls and other colloidal material. In the living twig, however, gas production interfered with water intake to some extent by the blocking of the tracheae.

In this connection, an objection may be raised as to the effect of the rarefied condition of the gases in the conducting tubes. This has been shown to be insignificant by the following experiment. Dead and living branches were mounted in empty manometers and left until a back pressure on the water in the U tube by the evolution of gases, was indicated. This took from six to 12 hours. Finally, the whole manometer was filled with water and the amount of absorption measured. No significant reduction in that absorption was noticed.

SUMMARY

1. Although much reduced during winter, the capacity of the pear trees used to absorb water was never entirely lost. Positive pressure of sap apparently never existed in the pear trees at any time during the winter and spring months.

2. From experiments with detached twigs both killed and living protected from evaporation and unprotected, it appeared that the so-called imbibitional property of cell walls and their contents is partly responsible for the capacity of the tissue to absorb water and may account for the filling up of the trees during the winter time.

The Distribution of Iron in Chlorotic Pear Trees

By YOUSIF MILAD,* *University of California, Berkeley, Calif.*

THIS paper is a preliminary report on the study of a pathological condition known as chlorosis which has, for several years, been troubling the pear orchards of the northern part of Santa Clara Valley, California.

The soil on which this type of chlorosis occurs is black adobe underlain at varying depths with a highly calcareous subsoil of very light gray color when not intermixed with the top soil. In many cases chlorotic and normal trees occur in different spots of the same orchard.

Chlorotic leaves turn to normal green when the trees are treated with ferrous sulphate applied by injection or to the roots. The

*I wish to acknowledge my indebtedness for valuable suggestions and criticisms to Dr. J. P. Bennett in whose laboratory and under whose supervision this work is carried out.

leaves respond in a few weeks and the fruit buds are formed generally in the second year after the treatment. Treated trees, however, usually revert to the chlorotic condition two or three years after the treatment if not treated again.

This non-failing response to iron applications and the gradual return of the chlorotic condition, suggested that chlorosis was due to an insufficient supply of iron in the tree. This might come about either from (1) lack of iron in the soil, or (2) failure of iron to enter the tree in sufficient quantity, or (3) failure of the entering iron to reach the growing points in an available form.

The first possibility appeared improbable because iron is usually present in all soils in enough quantities to meet the small requirement of plants. Moreover, the trees often grew normally while small when their root systems extended mostly through the black top soil, except in places where the light colored subsoil came close to the top soil As the trees became older, chlorosis occurred and appeared to be associated with the penetration of the root into the light-colored subsoil. Furthermore direct examination of the soil and sub-soil showed that abundant iron was present throughout.

The problem then appeared to be either a failure in the absorption of the iron by the tree, or in its utilization by the trees after absorption.

To determine which of these factors is playing the part, a comparative study of the distribution of iron in normal and in chlorotic pear trees was undertaken. Realizing that a more complicated situation exists in the tree than in the chlorotic annuals worked upon in previous studies, a complete analysis of the different parts of the tree including the root system was started.

The colorimetric sulphocyanate method adopted by the American Health Association (1) in the determination of iron traces in surface and ground waters and by Gile and Carrero in their work on rice and pineapple chlorosis, was used with slight modification. The modification made by Stokes and Cain (2) in this method was not followed completely owing to the long procedure involved in it. The results obtained are compiled in the following tables.

Discussion of Data on Trees Examined in the Dormant Season

As the percentage of ash in the chlorotic tree differs very markedly from that of the green tree and as variation also occurs in the ash content of the different parts of a given tree, as was found by actual determinations, we consider erroneous any comparison based on percentage of iron in ash. Percentage of iron in dry matter, on the other hand, offers a more sound basis for such comparisons.

A study of the data in Table I shows that there is no regularity in the distribution of iron in the tree. Iron content in the wood, however, tends to be more or less evenly distributed at least in the non-chlorotic trees, while in the bark, the distribution of iron is usually irregular and sharply fluctuating. Lucien and Leroux (3)

referred to the great variability in the iron distribution in the tissues of different plants. They found variation even in the sap-wood and heart-wood of the same trunk. Maquenne and Cerigelli (4) also speak of the irregularity of iron distribution in plant tissues and explain it on basis of variation in transpiration activities.

Table I

Distribution of Iron in Bearing Bartlett Pear Trees Examined in the Dormant Season

Part of Tree Analysed	Iron (Fe) Per Cent in Dry Matter				Iron (Fe) Per Cent in Ash			
	[a] Green	[b] Green	[c] Chlorotic	[d] Treated	[a] Green	[b] Green	[c] Chlorotic	[d] Treated
Top								
1-year growth:								
Wood	0.0010	0.0005	0.0004	0.0016	0.092	0.740	0.046	0.129
Bark	0.0072	0.0060	0.0037	0.0076	0.108	0.153	0.069	0.162
2-year growth.								
Wood	0.0013	0.0006	0.0008	0.0018	0.120	0.960	0.082	0.189
Bark	0.0120	0.0053	0.0086	0.0106	0.125	0.125	0.152	0.182
5-year growth:								
Wood	0.0009	0.0010	0.0008	—	0.133	0.227	0.101	—
Bark	0.0115	0.0083	0.0038	—	0.231	0.144	0.115	—
6-year growth·								
Wood	—	—	0.0015	0.0017	—	—	0.185	0.168
Bark	—	—	0.0090	0.0080	—	—	0.182	0.127
Trunk:								
Wood	0.0008	0.0008	0.0006	0.0020	0.160	0.173	0.153	0.263
Bark	0.0120	0.0083	0.0234	0.0135	0.219	0.125	0.334	0.127
Root								
A main root:								
Wood	0.0013	0.0017	0.0022	0.0077	0.263	0.295	0.300	0.850
Bark	0.0152	0.0079	0.0311	0.0770	0.202	0.268	0.705	1.070
5-year growth:								
Wood	0.0017	0.0022	0.0009	0.0018	0.197	0.330	0.149	0.192
Bark	0.0083	0.0062	0.0043	0.0114	0.131	0.194	0.119	0.284
4-year growth:								
Wood	—	0.0022	0.0028	—	—	0.310	0.388	—
Bark	—	0.0107	0.0211	—	—	0.224	0.605	—
2-year growth:								
Wood and Bark	0.0084	—	0.0155	0.0655	0.260	—	0.605	1.78
1-year growth:								
Wood and Bark	0.0262	—	—	—	0.850	—	—	—

(a). A normal green tree 10 years old obtained from an orchard which never had chlorosis; soil loamy.
(b). A normal green tree 10 years old, from a chlorotic orchard, soil calcareous.
(c). A chlorotic tree 9 years old from same chlorotic orchard, soil calcareous.
(d). A green tree 9 years old from same chlorotic orchard, once chlorotic and became green by $FeSO_4$, application to roots.

Irregularity in iron distribution is more marked in the chlorotic tree than in the green tree. We are not able to account for that. We are inclined to believe that these fluctuations in the chlorotic tree may account for the existence of green and yellow branches on the same chlorotic tree.

Comparison of the two green trees (a) and (b) offers a good example of variation in the amount of iron while both trees are functioning normally and were vigorous and productive. The tree (a) from a non-chlorotic orchard, contains in many of its parts nearly double the amount of iron found in the corresponding parts of tree (b) which comes from the chlorotic orchard. Such variation probably depends upon such factors as variability of individual trees, soil composition, water content, fertilizers applied and climatic conditions. Gile (5) analyzing leaves of green pineapples grown on three different types of soil found that Fe_2O_5 in ash was 6.87 per cent in plants grown on humus soils, 2.74 per cent on loam soils and 4.65 per cent on sandy soils.

Variability in iron content thus shows that green color does not necessarily depend on a fixed amount of iron. Apparently it depends on any amount, within the extremes, which supplies sufficient available iron to the leaves. The necessary amount of iron probably bears a close relation to the other ash constituents which in turn are conditioned by the mentioned factors.

In comparing the chlorotic tree (c) with the normal green tree (b), both being from the same orchard, we find that the chlorotic tree is by no means deficient in iron. In many parts, especially in the trunk and main root, it contains higher amounts of iron than the green tree. The variation between these two trees is less marked than between the two green trees (a) and (b).

Analysis of the treated tree (d) which was once chlorotic and recovered its green color by $FeSO_4$ application, offers the explanation of this recovery by showing a consistent increase in nearly every part of the tree over the chlorotic tree. It is interesting to notice the apparently undue drop in iron content of both bark and wood of the five year root. We believe that this may be due to the uneven application of $FeSO_4$ to the root system.

Discussion of Data on Trees Examined during the Growing Season

The analysis of the leaves shows that the chlorotic leaf is only slightly lower than the green, in iron content, and by no means deficient in it.

A comparison of the green tree (e) with the chlorotic tree (f) from the same orchard and of nearly the same age, shows that the top of the chlorotic tree is in many parts richer than the green tree in iron content. On the contrary, we find that the root system is poorer than that of the green tree. Owing to the small number of trees analyzed we feel unable to explain the increase of iron in the top and the decrease in the roots of the chlorotic tree unless it may be due to migration of iron caused by an immediate demand for it by the new growth. Maquenne and Cerigelli (4) believe that iron migrates with the other nutritive elements to the tissues which are characterized, or will be characterized, by the most vital activity. On the other hand, Gile and Carrero (6) speak of the immobility of iron.

The chlorotic tree (g) which was once treated with $FeSO_4$ and reverted to the chlorotic condition again contains nearly the same percentage of iron in the top as the green tree, with slight variations.

The preceding data show in a general way that the chlorotic pear tree is in no way deficient in iron as far as the absolute amount present is concerned. It is either equal or higher in iron content than the green tree with a few local deficiencies which cannot be held responsible for the chlorotic condition. Therefore, it seems that it is not possibly a question of difficulty in absorbing iron from the soil because the figures show that the chlorotic tree contains an abundance of it. In other words, the iron in this soil is available to the pear tree, but once in the tree it appears to be rendered unavailable to the growing points. If soluble iron is given to the tree either by

TABLE II.

Distribution of Iron in Bearing Bartlett Pear Trees Examined in the Growing Season

Part of Tree Analysed	Iron (Fe) Per Cent in dry matter			Iron (Fe) Per Cent in ash		
	[e] Green	[f] Chlorotic	[g] Chlorotic	[e] Green	[f] Chlorotic	[g] Treated
TOP						
Leaves	0.0094	0.0089	0.0093	0.179	0.213	0.102
Current Growth:						
Wood	0.0014	0.0027	0.0036	0.141	0.121	0.159
Bark	0.0051	0.0077	0.0099	0.122	0.129	0.179
1-year Growth:						
Wood	0.0014	0.0014	0.0010	0.149	0.116	0.140
Bark	0 0075	0.0099	0.0055	0.122	0.229	0.151
2-year Growth:						
Wood	0.0006	0.0007	0.0009	0.108	0.060	0.070
Bark	0.0042	0.0086	0.0066	0.073	0.185	0.153
5-year Growth:						
Wood	0 0007	0.0011	—	0.196	0.179	—
Bark	0.0064	0.0078	—	0.125	0.206	—
Trunk:						
Wood	—	0 0010	—	—	0.194	—
Bark	—	0.0037	—	—	0.057	—
ROOT						
A main root:						
Wood	0 0010	0.0007	—	0.216	0.134	—
Bark	0.0177	0.0041	—	0.270	0.085	—
5-year Growth:						
Wood	0.0031	0.0005	—	0 405	0.079	—
Bark	0.0242	0.0087	—	0.380	0.241	—
4-year Growth:						
Wood	0.0031	0.0011	—	0.405	0.115	—
Bark	0.0240	0.0023	—	0.380	0.067	—
2-year Growth:						
Wood and Bark	0.0405	0.0096	—	0.825	0.510	—
1-year Growth:						
Wood and Bark	0 0320	0.215	—	0.825	0.930	—

(e). Green Tree, about 10 years old from preceding orchard in chlorotic section.
(f). Chlorotic tree, eight years old from preceding orchard in Chlorotic section.
(g). Chlorotic tree, nine years old from preceding orchard in Chlorotic section (treated with $FeSO_4$ in 1921 and reverted to chlorotic condition in 1924.

injection or directly to the roots, the growing points and leaves get a sufficient amount in an available form and respond directly. Such applications apparently provide an excess of available iron for a season or two until completely consumed in growth or rendered unavailable by combination with certain substances. Masoni (7) has suggested that proteins or phosphates may be responsible for precipitation of iron within the tissues, thus rendering it inactive.

Further work is under way to determine the cause of unavailability of iron within the tissues.

SUMMARY

1. Normal and chlorotic pear trees on calcareous soils show distinct variations in the iron content of their different parts, especially in the root system and old wood. Fluctuations in the chlorotic tree are sharper than in the green tree and in the bark than in the wood.

2. The chlorotic pear tree taken as a whole is by no means deficient in iron. Some portions of it are slightly lower than the normal tree, but in many cases it is decidedly higher. Chlorotic leaves are slightly lower than green leaves in iron.

3. The chlorotic pear tree seems to suffer not from failure of roots to absorb iron, but from the unavailability within the tree of iron that has been absorbed.

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Preliminary Report on the Respiration of Apple Twigs During the Winter.[1]

By J. H. BEAUMONT and J. J. WILLAMAN, *Minnesota Experiment Station, St. Paul, Minn.*

AT THE University of Minnesota Fruit Breeding Farm, it is rapidly becoming necessary to devise some method of testing apple seedlings to supplement the natural hardiness test which they undergo during a Minnesota winter. The justification of an artificial method depends upon whether it works, or more explicitly, whether it is a more or less true index of the hardiness. Although it is known that varieties and seedlings differ in hardiness and that each varies around a certain standard, dependent upon its previous history and environment, no method has as yet been devised by which a prediction of the possible range or winter adaptability might be made of an untested seedling.

The respiratory activity of plants, seeds, seedlings, spores, etc., relative to temperature and various stimulative or antagonistic substances, has often been used as an index of metabolic activity. It was thought that the relative amounts of CO_2 evolved by dormant apple twigs of hardy and of tender varieties might be correlated with their ability to withstand low temperatures. During the winter of 1923-24, therefore, determinations were made of the CO_2 evolved at two different temperatures by two standard varieties of apples which differ widely in hardiness.

The trees used in the experiment were of the Delicious and Charlamoff varieties, the former being considered tender in Minnesota and the latter hardy. They had been grown in large half-barrel tubs for a number of years for greenhouse culture. Although the root systems were restricted, rather severe heading back and applications of fertilizer resulted in the trees making very satisfactory growths of from 18 to 24 inches. Neither variety had been p'aced in the greenhouse the previous spring and consequently each had the normal growing season and hardening off period of an orchard tree. Late in the fall the tubs were submerged in the soil at the east end of a greenhouse and a glass shelter, designed primarily for the comfort and convenience of the operator, was constructed around them.

The twig to be tested was surrounded by a glass tube about an inch in diameter, tapered at one end and with a side arm near the other end. A split rubber stopper was placed around the twig and securely forced into the tube, vaseline being used as a seal. An insulated box in which the temperature was accurately controlled was placed around the branch bearing the twigs to be tested. The box was heated by bulbs which were controlled by a Harvey thermoregulator. Inside of the greenhouse an air washing apparatus and a Truog tower for the absorption of CO_2 was set up. The air, washed

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TABLE I.

Respiration on Data on Apple Twigs for Winter 1923–24

Tree	Set	Number Twigs	5 3°C. CO_2 per 24 hours					12.4°C. CO_2 per 24 hours				
			Date	Per 100 cm. of twig	Per 100 g. of twig	Per 100 cc. of twig	Per 100 buds	Date	Per 100 cm. of twig	Per 100 g. of twig	Per 100 cc. of twig	Per 100 buds
				mg.	mg.	mg	mg.		mg.	mg.	mg.	mg.
I. Delicious (tender)	1	3	February 10	7.8	54	48	17.8	February 26	15.6	109	96	35.4
			February 19	8.0	56	49	18.2	March 16	16.0	111	98	36.3
			February 25	8.2	57	50	18.7	April 1	12.6	88	78	28.7
			March 17	8.5	59	52	19.3					
	2	4	February 8	10.3	89	84	24.3	March 4	19.5	169	159	46.1
			February 16	8.9	77	72	21.0	March 21	14.1	122	115	33.5
			February 23	7.3	63	59	17.3	March 22	15.3	132	124	36.2
			March 5	8.8	76	72	20.8					
	4	3	February 12	5.7	54	49	14.7	March 1	12.9	122	112	33.5
			February 21	5.9	55	51	15.2	March 14	10.8	98	90	27.0
			February 29	6.3	60	55	16.5					
III. Charlamoff (hardy)	2	3	February 7	9.6	118	106	37.8	March 11	11.6	142	128	45.5
			February 13	6.8	84	75	26.7	—	—	—	—	—
			February 22	8.1	100	90	31.9	—	—	—	—	—
			March 12	6.6	81	72	25.8	—	—	—	—	—
	3	3	February 9	13.9	131	107	50.8	—	—	—	—	—
			February 17	14.4	136	110	52.5	—	—	—	—	—
			February 24	14.5	137	111	53.0	—	—	—	—	—
	4	3	February 11	11.4	153	135	41.3	February 27	18.7	250	221	67.4
			February 20	7.9	106	95	28.7	March 15	13.3	177	157	47.8
			February 28	9.5	127	113	34.4	March 30	10.8	145	128	39.1

TABLE II

Average Weight of CO_2 in mg. Respired by Twigs of Charlamoff and Delicious Apples in February and March, 1924, at 5.3°C. and 12.4°C.

	Variety	5.3°C.	12.4°C.	Increase	Per cent Increase
mg. CO_2 Per 100 cm. of twig	Charlamoff	10.27± .63*	13.60± 1.04	3.33±1.22	32.
	Delicious	7.79± .30	14.60± .62	6.81±0.69	87.
	Difference	2.48± .69‡	1.00± 1.21		
mg. CO_2 Per 100 gm. of twig	Charlamoff	117.30±4.84	178.50±14.67	61.20±15.45	52.
	Delicious	63.64±2.28	118.88± 5.50	55.24± 5.95	87.
	Difference	53.66±5.34	59.62±15.67		
mg. CO_2 Per 100 cc. of twig	Charlamoff	101.40±3.77	158.50±12.81	57.10±14.71	56.
	Delicious	58.27±2.36	109.00± 5.59	50.73± 6.07	87.
	Difference	43.13±4.45	49.50±13.98		
mg. CO_2 Per 100 buds	Charlamoff	38.29±2.16	49.95± 3.56	11.66± 4.16	30.
	Delicious	18.53±0.54	34.59± 1.31	16.06± 1.42	87.
	Difference	19.76±2.22	15.36± 3.80		

free of CO_2 and from moisture (to prevent its freezing in the pipes), was pumped through copper and glass pipes to the tubes surrounding the twigs and back to the absorption tower. A combination of pressure and suction pumps kept the air flowing through the tubes at practically atmospheric pressure. The flow of air was continuous throughout the experimental period.

One tree each of Delicious and of Charlamoff was used. The terminal growths of each tree were grouped into three sets, each set consisting of three or four twigs. The box was alternated between the two trees and the sets on each tree were taken in sequence. Thus a set could not be used more frequently than once in six days. Longer periods usually intervened. The readings at 12.4°C. were usually made immediately after those at 5.3°C. on the same set.

In Table I are given the experimental data. The weights of CO_2 have been calculated on a basis of 100 cm. of length, 100 gm. of weight, 100 cc. of volume, and 100 buds. In Table II, the averages for each tree have been calculated, together wth their probable errors. The results are thus directly comparable.

These data indicate several differences which may be of interest in a consideration of relative behavior of hardy and tender apple twigs at these temperatures. At 5.3°C. the hardy Charlamoff variety gives off more CO_2 than does the tender Delicious, the differences in the light of the probable errors being significant, no matter which standard of measurement is used. At 12.4°C. the Charlamoff still gives off more CO_2 than the Delicious, but the difference is not as marked. The increase in total CO_2 given off by the Charlamoff is 30 to 56 per cent, and by the Delicious 87 per cent. The fluctuations in the former are no doubt due to the smaller number of determinations at 12.4°C.

In Table III the average weight, volume and number of buds per 100 cm. length of the twigs of each set used in the above determinations are given.

TABLE III.

Comparison of the Twigs of Delicious and Charlamoff Used in the Experiment Showing the Difference in Average Weight, Volume and Number of Buds per 100 cm. of Length of Each Variety.

Standards of Measurement	Variety		Difference Delicious over Charlamoff	Difference Per cent
	Delicious	Charlamoff		
Length cm.*	100.	100.0	.0	0
Weight gm.	12.1	9.0	3.1	34
Volume cc.	13.2	10.6	2.6	25
Number of buds	41.7	26.8	14.9	56

*The actual total length per set of the Delicious twigs was 118 cm. and of the Charlamoff 116 cm.

These data show that the Delicious twigs used in the experiment were 34 per cent heavier, had 25 per cent greater volume and 56 per cent more buds than the Charlamoff per unit of length. It was shown above that the Delicious gives off less CO_2 than the Charlamoff. The negative relationship of length, weight, volume and number of

buds to the total weight of CO_2 given off by the twigs of the two varieties used in the experiment, is suggestive of a possible cause of winter hardiness which may not be directly associated with the physical properties of the twig.

While it is conceivable that many factors may affect the total respiratory activity of the living cells of such a heterogeneous system of tissues as an apple twig, the writers believe that the differences in respiration noted between the two varieties are not due to winter injury or to handling. Both trees showed slight winter injury in the terminal pith, but the extent of injury in the tender variety was not strikingly greater than in the hardy variety. There was, furthermore, no evidence that the treatment to which the experimental twigs had been subjected had occasioned any injury. Neither did the vaseline used in sealing the twigs in the tubes have any apparent injurious effect either on the epidermis or the cortex immediately beneath. No bacterial or fungal activity was noted, nor did the twigs in any way appear abnormal at the termination of the experiment. The data show that during the period of experimentation, February and March, there was no progressive increase or decrease in CO_2 output in the various sets of twigs when measured at a given temperature. This would indicate that none of the internal factors which might be conceived to affect respiration, however, different they might be in the two varieties, had altered materially during the period of the experiment.

A difference in the duration of the rest period or even in the degree of dormancy between the two varieties might account for the observed difference in respiration Tests of the two varieties in question, as well as of several others, were made during the latter part of January and at times in February Twigs were removed from the trees and brought into the cool greenhouse and placed in water. At the end of two weeks all the varieties, both hardy and tender, had started active growth in the buds. Many of these subsequently formed good sized leaves and some blossomed. Similar experiments conducted by Mr. Hildreth on a more extensive scale showed that at that time of year and in the latitude of St. Paul, the 15 varieties tested reacted quickly to the changed environment and started active growth. Apparently, therefore, rest period or inability to react quickly to changes of temperature, has not played a differential part in the results obtained.

Further than the above considerations, the authors do not feel justified in suggesting any explanation of the cause of the difference in the respiration or the differential rate of increase with a rise in temperature. Further data are being accumulated which may possibly justify definite opinions.

Summary

The carbon dioxide output of twigs of a hardy apple (Charlamoff) and of a tender apple (Delicious) were measured during February and March, 1924, at 5.3°C. and at 12.4°C. At both temperatures the hardy variety respired the more, although the difference was

greatest at the lower temperature. These differences held for four bases of calculation,—unit of length, weight, volume of twigs and the number of buds. The CO_2 evolved by the twigs of the two varieties bears an inverse relationship to their weight, length, volume and number of buds. The difference in CO_2 evolved was not due apparently to differences in extent of rest period or of dormancy.

Influence of Soaking in Water upon the Germination of Asparagus.

By H. A. Borthwick, *University of California, Berkeley, Calif.*

This address will be printed in a bulletin by the California Experiment Station.

Development of Asparagus Seed with Special Reference to the Semi-Permeability of the Seed Coat.

By W. W. Robbins, *University of California, Berkeley, Calif.*

This address will be printed in the Botanical Gazette.

Root and Crown Development in Asparagus.

By W. W. Robbins and H. A. Jones, *University of California, Berkeley, Calif.*

This address will be printed in bulletin No. 381 of the California Experiment Station.

Floral Development, Pollination and Seed Development in Lettuce.

By H. A. Jones, *University Farm, Davis, Calif.*

This address will be printed in a bulletin by the California Experiment Station.

A Study of the Morphology of Celery in Relation to Quality

By C. B. Sayre, *University of Illinois, Urbana, Ill.*

SYSTEMATIC improvement in the quality of celery requires: first, a knowledge of the structural characters of the plant that are correlated with quality or lack of quality; and secondly, a knowledge of the conditions of temperature, moisture, plant food, stage of maturity and blanching that affect the structure of celery and its resulting relation to quality. It is the object of this paper

to present data and information concerning a microscopic study of the interior anatomy of the celery plant and to present some new views in regard to structural characters that seem correlated with quality.

For the purpose of a more definite understanding it will be assumed that celery to be of good quality must be crisp, tender and stringless; and have a pleasant, sweet, nut-like flavor.

Various investigators have defined quality in celery and have presented facts and theories in regard to factors which influence this quality. It is generally agreed that pithiness in celery is due to over-maturity which results in a breaking down of the parenchyma cells. The tendency to pithiness has also been shown to be an inherited characteristic. Flavor is of course greatly influenced by the degree of blanching, and likewise by the variety, some varieties being of much richer, sweeter flavor than others grown under identical conditions. Crispness in celery is said to be due entirely to the relative water content of the plant, celery being crisp when the cells are turgid. A number of factors such as temperature, moisture, nitrogen supply, over rapid growth, or a check in growth, or poor storage conditions, may affect the turgidity of the cells and consequently reduce the crispness of celery.

Stringiness in celery is said by some investigators to be due to an enlargement of the fibrovascular bundles or to the development of woody tissue in and around the fibrovascular bundles.

The following discussion will attempt to disprove these theories in regard to stringiness in celery. The investigations herein reported and which involved a microscopic examination of several hundred cross sections of celery stalks would indicate that stringiness in celery is not due primarily to the fibrovascular bundles but to an entirely different morphological condition not previously mentioned in the literature regarding celery, namely, the relative hardness of the collenchyma tissue.

This investigation involved a critical comparison of eight varieties of celery and a comparison of some varieties grown under varying conditions of moisture, fertility, blanching, etc. Typical specimens were selected from each lot and were first given a quality rating based on an eating test. For this test the celery was first trimmed as for market, then the three outer leaves were removed and the fourth one taken for sampling. For the microscopic examination a section one inch long was then taken of each stalk one inch above the point of attachment. Coarse outer stalks and tender inner stalks of the same plant were also included in the test.

The sections were first fixed in picric acid, which was then washed out and the specimens imbedded in paraffin. Sections nine microns in thickness were then made of each section and these were stained in safrinin and in haematoxylin. Both longitudinal and cross sections were made. These sections were then studied under a microscope and the structural differences were critically compared.

This examination revealed the following structure of the celery petiole. Entirely surrounding the section is the epidermal layer one

cell in depth. On the outside of the epidermis a thin, water proof film of cutin forms the cuticle. Inside the epidermis is the collenchyma tissue which occurs as separate strands in the "ribs" or corrugated portion around the exterior side of each stalk; and also as a continuous layer about two cells in depth next to the epidermis. This layer of collenchyma is often deeper on the interior side of each stalk. The collenchyma cells are thick-walled, especially at the angles. In longitudinal section these cells are long and pointed and inter-laced thus forming a strong tissue. Arranged as it is near the periphery, the collenchyma embodies the mechanical structure that gives the greatest resistance to bending stresses.

Parenchyma tissue lies next to the collenchyma internally and constitutes the greater part of the stalk structure. The cells in this tissue are large and irregular and thin walled. Pithiness in celery is undoubtedly due to a breaking down of large areas of these cells thus leaving open spaces through the center of the stalk.

There is a line of large fibrovascular bundles situated about one-third of the distance in from the exterior side of the stalk. There is also a secondary line of a large number of small bundles located parallel to and about one-sixth of the distance in from the interior side of the stalk. These secondary bundles seem to be quite similar to the primary vascular bundles except that the secondary bundles are smaller and the phloem sheath is not so well developed.

Scattered throughout the parenchyma at irregular intervals are some peculiar glands or oil ducts. Probably these glands secrete essential oils and have some relation to flavor, but this relation was not established. There was no connection between the number of these glands and flavor. Heredity, that is, the horticultural variety seems of greater importance than environment in affecting flavor. Of course, proper blanching is essential to good flavor.

In comparing the effects of various methods of blanching an interesting feature was observed that might be mentioned here although it proved to be of lesser influence than expected in its effect on the quality of the blanched celery. It was found that celery blanched with composition paper became very warm on sunny days. In late October the temperature variation in 12 hours was 27 degrees in celery blanched with R. and D. paper, 18 degrees in celery blanched with boards, and only 2 degrees in celery blanched with soil. Undoubtedly this temperature variation would be even greater in the longer warmer days of August and September. As might be expected, the lower and more even temperature of the soil blanching resulted in superior quality of the celery.

In the microscopic study of celery structure, extremely contrasting cases such as a very tender, and a very stringy specimen were first compared to note differences in structure; and finally all specimens were carefully examined. As a consequence of this microscopic examination, some negative results as well as positive results seem worthy of consideration.

First, the number of fibrovascular bundles in tender specimens was compared with the number of these bundles in tough specimens.

Then the size of the bundles was compared in each case; but there seemed to be no differences either in the number or the size of the bundles that are consistently correlated with either phase of quality. Apparently there is a rather constant size of the fibrovascular bundles within the horticultural variety, but some varieties have larger bundles than other varieties and large bundles are not correlated with tougher or stringier varieties. In fact, one of the most tender varieties studied had unusually large bundles, although another tender variety and a very stringy variety both had very small bundles. The fibrovascular bundles are smaller in the smaller inner stalks on the same plant than in the large outer stalks but are in proportion to the entire size of the stalk.

The number of fibrovascular bundles in a stalk likewise seems to have no relation to stringiness or toughness of celery. There is a great variation in the number of bundles in different stalks from the same or different varieties and even in different stalks from the same plant. Moreover, there is no increase in the number of bundles in tough, stringy specimens as compared to tender specimens.

The size of the xylem and the proportionate number of large tracheal vessels was then compared in tender and in stringy specimens. Again the results were negative, a large xylem and a great number of large tracheal vessels being found in both tough and tender specimens and likewise the opposite condition was found in each case.

Then the structure of the phloem sheaths was carefully compared in regard to size of the phloem, relative size and thickness of these cell walls, and shape of phloem sheath; that is, whether it extended well down around the xylem in a horse-shoe shape or not. But in all of these phases of the plant structure, the differences noted did not seem to be correlated with differences in quality of celery. Although considerable variation was observed in the structure of different specimens, yet similar variations in each of these characters were found in specimens markedly different in quality.

Micro-chemical tests with phloroglucin and also with chloroiodide of zinc showed lignification in only two kinds of tissue, namely the large tracheal vessels and the oil glands or ducts. The same lignification was found in tender inner stalks as in the tough outer stalks and there were no additional lignified elements in the tough, stringy specimens. The spiral and annular reinforcement in the tracheal vessels in all specimens seemed particularly lignified and the tracheal tubes in the secondary bundles showed the same lignification as the tracheal tubes in the primary bundles. Since lignin is often associated with hard, tough tissue, the relation of these lignified elements to stringiness must be considered. However, no correlation could be found between the number or size of the lignified elements and stringiness. Since botanists have proven that lignified tissues are not always of tough, hard texture and that pure cellulose walls may be of greater hardness and toughness than lignified tissue, it seems evident that this is the case in celery.

Another negative result that should be mentioned is that no bast fibers, wood fibers, or stone cell tissues were found in any of the celery sections. This eliminates three of the four plant skeletal tissues from further consideration in relation to stringiness of celery.

Since there are only four kinds of plant skeletal tissues, namely (1) collenchyma, (2) bast fiber, (3) wood fiber, and (4) stone cell tissue, and since the last three of these tissues are not present in celery it would seem that the collenchyma tissue must have some relation to stringiness in celery.

A superficial examination of stringy celery would support this belief; because, if a stringy celery stalk is broken so that the "strings" tear out, it can be readily seen that the "strings" are in the "ribs" where the collenchyma strand is found. This is likewise in accordance with the statement of the plant anatomists that "collenchyma regularly forms the skeletal system of growing organs, and often serves as the permanent mechanical tissue in many fully grown herbaceous structures such as leaf petioles," which of course is the case with celery.

Apparently the relative amount of collenchyma tissue in the ribs is not a factor in causing stringiness because many tender specimens have relatively large strands of collenchyma. The size of the collenchyma cells and thickness of cell walls likewise seem to have no bearing on stringiness of celery. However, there seemed to be a great variation in the degree of hardness of the collenchyma cell walls. Furthermore, there was a definite relation between the degree of hardness of the collenchyma tissue and stringiness of the celery petiole. The collenchyma tissue in tough, stringy specimens seemed to be of such particularly hard texture that these cells would break or tear instead of permitting a clean cut in sectioning. On the other hand, in tender specimens both of tender varieties or inner stalks of tough varieties, the collenchyma cell walls did not seem to be hardened as shown by the fact that they would make a clean cut and a clear, distinct cross section. This greater hardness of the collenchyma tissue was the only morphological condition that seemed to be correlated with toughness and stringiness in celery.

Experimental Studies of the Effects of Cultivation on Certain Vegetable Crops

By H. C. THOMPSON, *Cornell University, Ithaca, N. Y.*

IN SOIL management and crop production literature great emphasis is placed on the advantages claimed for cultivation or intertillage. Even greater emphasis is placed on the importance of cultivation in vegetable production than in growing of other farm crops. In spite of the great importance attached to intertillage of vegetables, very little experimental work has been done on the problem. This may be due to the fact that the theories of the benefits derived from cultivation have been set forth, and accepted by most

of us, as facts rather than as theories. It is usually stated that cultivation increases the yield of crop plants due to one or more of the following factors:

1. Conservation of moisture due to the formation of a soil mulch which checks evaporation at the surface.
2. Destruction of weeds, thereby conserving moisture and raw materials in the soil.
3. Increased rate of nitrate formation and release of other nutrients in the soil.
4. Increased aeration, which would affect nitrate formation and growth of soil organisms.
5. Increased growth of beneficial soil organisms.
6. Increased absorption and retention of heat.

The writer has confined his attention largely to the effects of cultivation on yield, on soil moisture, and on soil temperature. In connection with these, studies have been made on the root systems of the plants used in these experiments to determine whether or not there is any correlation between the root system and the response of plants to cultivation.

Outline of Experiments

The experimental work reported in this paper has been conducted in the gardens of the Department of Vegetable Gardening, Cornell University, during the five years, 1920 to 1924, inclusive. The soil used is classed as Dunkirk gravelly, sandy loam of very good texture and fair fertility. The surface soil is eight to 12 inches deep and is underlain by a gravelly sandy loam, becoming more sandy as the depth increases. Each year the soil has been plowed in the fall and planted to rye. During the winter or spring, manure has been applied at the rate of 15 to 20 tons per acre, and this has been turned under with the rye. A moderate application of fertilizer has been applied each year and the soil given thorough preparation.

Six crops have been used in these experiments, beets, carrots, onions, cabbage celery and tomatoes. Seeds of beets and carrots were sown in place in rows 18 inches apart as soon as the conditions were favorable, and the small plants thinned at the proper time. Onion, cabbage, celery and tomato plants were grown in the greenhouse and set to the field as early as it was deemed safe. Onion plants were set three by 18 inches, cabbage 18 by 36, celery six by 36, tomatoes 18 by 36 for those grown under the single stem training method, and 48 by 48 inches for those plants grown without any pruning or training. In all cases a good strain of a standard variety has been used.

Each treatment has been in triplicate, the plats being five rows wide and 20 feet long for all of the crops except tomatoes, where the rows were 32 feet long. Outside rows and those separating the plats have not been included in the harvest records, so that the yield recorded is that produced on four rows in each plat or 12 rows in each treatment each year. Only three treatments have been given:

(1) cultivation once a week, using a hand cultivator, (2) no cultivation, weeds cut off at the surface of the ground with a sharp hoe (referred to as "scraped" in this paper) and (3) no cultivation, weeds allowed to grow.

Effect of Cultivation on Yield

In these experiments great care has been taken to secure accurate yield records, including number and weight. The average annual yield per plat is given in Table I. The yields include only the marketable portion of each crop.

Table I.

Effects of Cultivation on Yield of Six Vegetable Crops at Ithaca, New York, 1920–1924

Crop	Average yield per plat per year						Percentage yield Scraped Cultivated
	Cultivated		Scraped		Weed plat		
	Number	Pounds Weight	Number	Pounds Weight	Number	Pounds Weight	
Carrots	602.92	83.31	633.00	78.75	—	—	94.5
Beets	370.73	54.38	369.85	52.27	152.4	8.61	96.0
Onions	274.31	69.21	274.08	62.55	—	—	90.0
Cabbage	49.06	116.06	50.03	118.21	—	—	101.7
Celery	144.00	138.00	141.80	106.36	—	—	77.0
Tomatoes, Tr	577.69	167.24	565.22	161.58	—	—	96.6
Tomatoes, Untr	768.92	208.58	776.82	203.46	—	—	97.5

An examination of Table I shows that the average yield was higher in the cultivated plats than in the scraped plats with all crops except cabbage. The difference, however, is very slight with all crops except onions and celery where the scraped plats produced 90 and 77 per cent, respectively, as much as the cultivated plats. The average yield of the scraped plats of carrots was 94.5 per cent of the cultivated; with beets 96 per cent, cabbage 101.7, trained tomatoes 96.6 and untrained tomatoes 97.5 per cent. With the exception of onions and celery, the difference in yields between cultivated and scraped plats is within the range of experimental error and is considered insignificant. Celery is the only crop which consistently has shown a large gain for cultivation, the lowest difference being 18 per cent and the highest 26 per cent. Two years out of five the yields of carrots have been practically the same under the two treatments. With beets, the scraped plats produced slightly more than the cultivated plats two years, while in the other three years it was the reverse, the greatest gain for cultivation being during the very dry season of 1923. With onions the scraped plats have produced a larger crop than the cultivated plats two years out of five, but in one of these the advantage was due to washing away of the loose soil in the cultivated plats. Scraped plats of cabbage have

been ahead three years out of five. There has been no significant difference in yield between cultivated and scraped plats of tomatoes any year except 1921.

The effects of weeds on yield of beets is very marked in spite of the fact that weed growth was very light two years out of five. The weed plats have produced less than a fifth as much as the cultivated or scraped plats. When the weed growth was heavy no edible beets were produced, even though the total weight of weeds and beets on the weed plats was less than the weight of beets alone on the cultivated, or scraped plats.

Effects of Cultivation on Soil Moisture

During the past four years moisture determinations have been made every two weeks from soil samples taken to the depth of 30 inches. Three borings were made in each plat and the soil was well mixed before drawing the sample. The samples were placed in glass jars which were sealed immediately and taken to the laboratory where they were weighed into aluminum pans and dried in an electric oven to constant weight. Table II shows the average and minimum percentage of moisture for each year. It would be better to present the data for each determination rather than the average of all, since under some conditions, the scraped plats show a higher moisture content and under others the cultivated plats are ahead. Space does not permit of giving all of these data. No direct comparison between crops can be made from the data in this table since the period covered by the growth of the crops was not the same. For example, the sampling of the soil in the cabbage plats began May 3 and ended July 25, 1924, whereas the sampling of the tomato plats began June 28 and ended September 16.

A study of Table II shows that the effects of a soil mulch on moisture was not always the same. In 1921, the average percentage of moisture was higher in the cultivated than in the scraped plats of all the crops. In 1922, the scraped plats of beets and carrots had a higher average and also a higher minimum moisture content than the corresponding cultivated plats; with onions the two treatments were practically the same, while with cabbage, celery, tomatoes and fallow the cultivated plats averaged higher in moisture. In 1923, the results were nearly the reverse of 1922, the cultivated plats of beets, carrots, onions and celery, averaging higher in moisture than the corresponding scraped plats, while the opposite was true with cabbage and both trained and untrained tomatoes. The cultivated and scraped fa low plats averaged practically the same moisture content. In 1924, all cultivated plats except the fallow averaged higher in moisture than the corresponding scraped plats, but during a large part of the season moisture was not a limiting factor. It did not always follow that the plats having the highest average moisture content produced the highest yield. There are several possible explanations for this, the most plausible one being that, at some critical period during the growth of a crop, the mois-

ture conditions on these plats were less favorable than on those which averaged lower for the season. It is evident that maintaining a soil mulch does not always result in the conservation of moisture. In fact, under some conditions cultivation results in the loss of moistture. This is especially true of cultivation following a light rain which wets only the surface two or three inches of soil. Stirring the soil hastens evaporation of water from the surface, and under the conditions mentioned, results in the actual loss of moisture as compared with uncultivated soil. In many cases a soil mulch conserves moisture by preventing "run off," rather than by checking evaporation. This is mentioned merely to suggest that too much emphasis has been placed on the maintenance of a soil mulch to check loss of moisture brought to the surface by capillary action.

TABLE II.

Effects of Cultivation on Soil Moisture.

Crop and treatment	Average and minimum percentage, 1921-1924							
	1921		1922		1923		1924	
	Average	Minimum	Average	Minimum	Average	Minimum	Average	Minimum
Beet C.	9.05	5.10	9.80	7.35	8.19	4.23	12.04	7.75
" S.	8.33	4.80	11.12	7.64	7.98	4.17	11.18	7.99
" W.	7.66	4.70	9.97	5.93	6.86	2.78	11.21	6.83
Carrot C.	8 73	6.30	11.12	5.91	9.00	5.16	13.12	8.46
" S	8.24	5.80	11.46	6.88	7.96	4.72	12.35	8.80
Onion C.	11.36	9.80	11.23	7.13	9.50	7.75	12.04	9.40
" S.	10.43	8.40	11.25	6.59	9.38	7.52	11.21	9.40
Cabbage C.	9.96	4.90	13.83	9.80	10.48	5.15	11.08	8.57
" S.	9.62	5.40	13.31	9.49	10.57	5.71	10.28	7.06
Celery C.	10.07	7.60	13.47	9.76	11.57	6.95	10.81	9.40
" S.	8.80	6.70	11.75	6.24	11.31	7.52	8.56	7.18
Tom.Tr.C.	7.95	6.40	13.15	9.22	8.66	7.52	11.70	10.98
Tr.S.	7.40	6.00	12.47	9.53	9.80	7.65	11.61	10.13
" Untr.C.	9.20	8.20	14.01	10.71	10.10	6.48	12.44	11.11
" " S.	7.70	6.80	12.94	8.14	11.81	7.98	11.26	10.13
Fallow C.	—	—	15.33	12.93	10.34	8.93	11.57	10.37
" S.	—	—	14.87	12.39	10.36	8.81	13.21	10.49

There is a fairly good positive correlation between moisture conservation by the treatments given and the yields of the various crops. Soil moisture records are available for the four years 1921 to 1924 and for this period we have 28 sets of yield data and the corresponding sets of moisture data. In 18 out of the 28, the higher yield and higher average soil moisture were on the same treatments; in eight others there was practically no difference in yields under the two treatments and soil moisture apparently was not a limiting factor in six of these instances. In the other two cases, there was a negative correlation, but in one of these the difference in moisture between the two treatments was negligible. In other words, where cultivation conserved moisture, it also increased yield and where it resulted in loss of moisture, the yield was decreased.

Effects of Cultivation on Soil Temperature

In agronomic literature, one of the advantages claimed for maintaining a soil mulch is the increased absorption and retention of heat. This, it is explained, is due to the mulch checking evaporation and retarding loss of heat by radiation. In order to secure some

TABLE III.

Effects of Cultivation on Soil Temperature, Ithaca, N. Y., 1923 and 1924

Week ending	Temperature degrees Fahrenheit—Weekly average					
	In Beet Plats				In Fallow	
	Three inches deep		Five and Six inches deep		Five and Six Inches deep*	
	Cult	Scr	Cult	Scr.	Cult.	Scr.
1923						
May 31... ...	65.1	68.1	61.9	63.5	61.7	61.9
June 7.. .	69.6	71.2	68.5	69.1	65.8	67.8
" 14.. ...	61.9	63.9	60.9	61.1	60.2	60.5
" 21.. ..	72.1	76.9	69.7	71.7	70.6	71.0
" 28..	76.6	81.4	75.0	76.8	75.8	76.4
July 5...... .	69.3	73.4	69.0	70.8	69.1	69.9
" 12..... ..	73.6	78.6	71.7	74.3	73.1	74.0
" 19......	75.4	80.0	72.9	75.7	74.3	75.5
" 26	72.8	77.8	71.1	74.2	72.4	74.1
August 2. .. .	70.8	72.4	68.9	69.9	69.8	70.4
" 6.	77.7	81.3	74.7	75.9	77.4	78.6
1924						
May 21...	51.8	51.6	50.9	50.1	50.4	51.2
" 28... .. .	53.8	54.1	51.7	52.2	52.3	53.0
June 4...	56.3	57.4	54.2	55.1	54.5	54.7
" 11... .. .	60.3	61.6	57.1	58.6	57.8	57.6
" 18..........	67.5	69.2	63.2	64.6	63.1	63.9
" 25........	74.2	74.7	69.6	71.0	70.1	71.1
July 1....... .	69.1	68.8	65.5	66.9	66.3	67.3
" 8....... .	71.6	71.8	68.2	69.3	69.9	71.2
" 15.........	70.3	71.3	68.3	69.9	70.0	71.9
" 22..........	68.9	69.1	65.6	66.5	67.4	69.4
" 29..........	74.7	74.9	69.5	71.3	71.3	73.9
August 5........	67.1	68.0	66.1	67.0	68.0	69.8
" 12........	68.3	69.4	68.3	68.4	70.8	72.4
" 19........	—	—	—	—	65.6	67.2
" 26........	—	—	—	—	68.3	69.4
September 2.....	—	—	—	—	70.2	72.3
" 9.....	—	—	—	—	59.3	60.8
" 16.....	—	—	—	—	57.2	58.2
" 23.....	—	—	—	—	59.4	60.1

*Five inches deep in 1923, six inches deep in 1924.

data on this subject in connection with the cultivation experiments with vegetables conducted by the writer, soil temperature records were secured during the growing seasons of 1923 and 1924. In 1923, records were secured for three and five inch depths in cultivated

and scraped plats of beets, and at the depth of five inches in fallow. In 1924, the records were for three and six inch depths in the beet plats and at the six inch depth in the fallow plats. Soil thermometers were placed in the soil to the depths mentioned and readings were taken daily at 7 A.M., 1 P.M., and 5 P.M. The daily and weekly averages were calculated from these readings. Table III gives the average weekly temperature for 1923 and 1924.

During the two years, 1923 and 1924, the temperature of the soil at three and five to six inch depths, in both cropped and uncropped areas was higher in the scraped plats than in corresponding cultivated plats. In 1923, the difference averaged 3.70 degrees at the three-inch depth in the beet plats, 1.8 degrees at the five-inch depth in the same plats and 1.0 degree in the uncropped plats. In 1924, the difference in temperature between the two treatments at both depths in the beet plats was less than in 1923, averaging 0.6 degree difference at three inches deep and 1.0 degree at five inches deep. The scraped fallow plat averaged 1.2 degrees higher in 1924 than the corresponding cultivated plat. The uncropped soil averaged higher in temperature than the cropped under the two cultural treatments, but the difference was small. While the differences in temperature of the soil under the various treatments are not very large and may not be of any particular significance they are very consistent, there being only three exceptions in the 78 comparisons of weekly means.

As just suggested, the differences in temperature recorded may not be especially significant, it seems probable that at times the higher temperature may be of advantage to the crop and at other times, it may be the reverse. For example, in 1923 when the weekly mean temperature three inches deep in the scraped plats of beets ranged between 72 and 81 degrees F., for several weeks, some of the processes going on in the soil might have been injuriously affected. During this time the temperature in the scraped plats averaged from three to five degrees higher than in the corresponding cultivated plats.

Root Studies

A careful study has been made of the root systems of the plants used in the cultivation experiments. It was thought that possibly the difference in the character and distribution of the roots might explain why the crops respond differently to cultivation. In general it may be said that those crops which have relatively large and well distributed root systems respond less to cultivation from the standpoint of a soil mulch, than those with smaller or more restricted root systems. Celery and onions are examples of the latter type, while cabbage is an extreme example of the former.

Where the root system is large and well distributed, there is less moisture conservation than where the system is relatively small and restricted. This may be due to the roots absorbing the moisture as it rises, thus preventing it from reaching the surface. With a well distributed root system, as developed by cabbage, more moisture would be intercepted than would be the case with a more restricted

system such as that of celery. The roots of cabbage, by the time the plants are half grown, extend well beyond the centers between the rows, while those of celery are confined very largely within a radius of six to nine inches of the plant, thus leaving a space of 18 inches or more between the rows with very few roots. Moisture rising through this space between the rows of celery would not be intercepted and therefore would reach the surface and be lost. Plants with many roots near the surface between the rows are at times injured by the cultivation and this injury may offset any advantage derived from a soil mulch.

SUMMARY

The data presented seem to justify the following conclusions:

1. The main advantage of cultivation is weed control and this is of very great importance.

2. The effects of a soil mulch on moisture conservation have been greatly exaggerated in popular literature on gardening. Under some conditions a soil mulch conserves moisture while under others it has the opposite effect. Even where moisture is conserved by a soil mulch the advantages may be lost because of injury to the roost by cultivation when the plants are large and the root systems well developed.

3. Crops differ in their response to cultivation for purposes other than weed control. Celery and onions are the only crops used in these experiments which have given large and consistent gains for maintaining a soil mulch.

4. In general, there is a positive correlation between moisture conservation and crop yield, but this was not always the case.

5. Contrary to the common belief, a soil mulch, as compared with bare surface, has lowered the temperature during the growing season. During a dry season the temperature difference between cultivated and scraped plats was greater than during a relatively wet season. Uncropped soil averaged higher temperature than cropped soil at three and five to six inch depths.

6. There is an apparent correlation between the root system and the response to cultivation. Plants having a large and well distributed root system respond less to cultivation, for purpose of maintaining a soil mulch, than plants with a relatively small and restricted root system. There is also less moisture conservation from cultivation with the former than with the latter type of root system.

7. Continuing cultivation when there are no weeds and a soil mulch is already formed results in unnecessary labor and expense. In fact, under these conditions cultivation, is often positively injurious. The mulch is increased in depth at each cultivation, thus destroying the roots and decreasing the water, making it impossible for the plants to get any moisture or nutrients from the surface three or four inches.

The Acid Tolerance Range of Spinach (*Spinacea oleracea*)

By H. H. ZIMMERLEY, *Virginia Truck Experiment Station, Norfolk, Va.*

A CLOSE correlation between soil acidity and the growth of spinach (*Spinacea oleracea*) has been noted in the Norfolk trucking area. Low percentage of germination, yellowing and browning of the margins and tips of the seedling leaves, browning of the tap roots and rootlets, death of many of the plants and a slow growth of the remainder, are usually indicative of a very acid soil condition. The boundaries of areas of different degrees of acidity in the same field are frequently well defined by the variations of plant growth. The largest losses attributable to soil acidity are usually incurred where potatoes (*Solanum tuberosum*) and spinach are grown in rotation and the soil has been kept in an acid condition to prevent injury to the potatoes by the common scab organism (*Actincmyces scabies*). The problem (*) thus presented was one of determining the degree of acidity favorable for a satisfactory growth of the spinach plant, but detrimental to the development of the potato scab organism. The preliminary results of that part of the work pertaining to the acid tolerance range of spinach as indicated by the hydrogen-ion concentration of the soil and its lime requirement are discussed in this paper.

That the hydrogen-ion and hydroxyl-ion concentration of either nutrient solution or soil has a marked effect on the growth of many species of plants, has been shown by Hoagland (6), (7), McCall (12), Tarr and Noble (13), Wherry (15), Kelley (11) and others. Burgess and Pember (3), have prepared a tentative classification of comparative resistances of certain plants to soil acidity and active aluminum. Spinach is listed among those crops which require for normal development a pH value of above 6, signifying a lime requirement by the Jones method of less than 1500 pounds of CaO per acre.

EXPERIMENTS IN 1923 AND 1924

Twenty-four glazed terra cotta tiles, 15 inches in diameter and 24 inches in depth, set in the ground with the upper four inches of the tile extending above the surface of the surrounding soil, were filled to within four inches of the top with Norfolk gravelly loam. This soil, which was secured from a plat that had been fertilized with sulphate of ammonia during the preceding 12 years, showed a decidedly acid reaction. The soil in some of the tiles was treated with alkali and in others with sulphuric acid to secure the desired acidity and alkalinity range as shown in Table I. During November, 1923, 50 grams of dry ground fish scrap fertilizer and 2.25 kilograms of well decomposed stable manure were mixed with the upper six inches of soil in each tile. In September, 1924, two grams of

*A cooperative project by Dr. Ray J. Davis, Plant Pathologist at Virginia Truck Experiment Station, 1923–24, and the writer.

commercial fertilizer analyzing nine per cent ammonia, five per cent phosphoric acid and three per cent potash were added to each tile in order to furnish an abundance of readily available plant food. In addition to the tiles, field plats 20 feet wide by 135 feet long, located on a fertile area of Norfolk loam having a pH value of about seven were used to determine the effect of different degrees of acidity on the spinach crop when grown on a field scale. Plats one, two, three, and four were treated with 129.6, 97.2, 64.8, and 32.4 liters of sulphuric acid, respectively. Plat five was left untreated. A commercial fertilizer of the same formula as used in the tiles was applied at the rate of 800 pounds per acre before the crop was planted. All hydrogen-ion and hydroxyl concentrations were determined electrometrically except for the preliminary work in 1923, at which time colorimetric readings were taken of the soils in the tiles before the first spinach was seeded. Readings of the hydrogen-ion cencentrations of the soil solutions on both field and tile plats were made in August, 1924, before the spinach was planted and again in November when the crop had reached maturity

The outfit used in making the determinations was equipped with a special gas cell and shaker designed by Knight (9), a saturated calomel cell of the Hildebrandt type, a lamp and scale galvanometer, two slide rheostats, Eppley cell, simplified Leeds and Northrup potentiometer, and necessary accessories Duplicate readings were made of all samples and the accuracy of the outfit frequently tested by checking with readings of twentieth normal acid potassium phthalate solution

With the exception of the more acid soils there was a distinct increase in the hydrogen-ion concentration between August, 1924, when the first determinations were made, and the latter part of November, 1924, when the second set of readings was taken. This may have been largely due to leaching of the bases on the more alkaline plats and absorption of bases by the subsoil acids which rose to the surface by capillary action. An average of the pH values of the two determinations are taken as the basis for comparison of the relative effect of the hydroxyl and hydrogen-ion on germination and growth.

In order to simplify the presentation of data the 24 tiles have been divided into five groups, based on the pH values of the soils. A, comprises the hydroxyl group with pH values greater than 7.0; B, those between 6.5 and 7.0; C, those between 6.0 and 6.5; D, those between 5.5 and 6.0; E, all below 5.5. The pH values of the soil in each tile within the different groups as determined in 1924 are given in Table I.

One hundred spinach seeds of the Virginia Savoy variety were planted in each tile on November 19, 1923, and germination counts made on December 4. At this time samples of soil were taken from each tile and the hydrogen-ion reactions determined by the colorimetric method. In those tiles having soil pH values above 7.0, the germination was 72.2 per cent; between pH 6.5 and 7.0, 53.7 per cent; between pH 6.0 and 6.5, 43.7 per cent; at pH 5.8, 5 per cent, and be-

low pH 5.8, no germination occurred. Because of the late date at which the seed was planted and the lack of available plant food in the soil, the plants made very little growth during the winter months and in early spring produced seed stalks without the production of sufficient vegetative growth to indicate much correlation between the degree of soil acidity and crop yield.

One hundred spinach seeds were planted in each tile on September 9, 1924 On September 23, 1924, germination counts gave the following average percentages for the various groups: A 69, B 57, C 39, D 36, E 40. The seed in group A, where the soil gave an alkaline reaction, germinated several days earlier than in the more acid groups. The effect on germination was most marked between groups B and D where a rise of .5 pH gave an increase of 18 per cent in germination. On October 22, the plants were thinned to a stand of five in each tile and the average height of the plants in each was noted. The average heights were: 11cm. in group A; 11.4 in B; 9.4 in C; 7.6 in D; and 3.4 in E. This represents an increase of 335 per cent in height between the plants grown on the very acid soils with a pH value of less than 5.5 and those in the group with reaction values between pH 6.5 and 7.

Where the soil pH value was above 6.0, the young plants were vigorous and of good color. In group E where the hydrogen-ion concentration was greater than pH 5.5, many of the seedlings died and the remainder were in an unhealthy condition. The margins of the leaves were either yellowed or parched, and the roots in many cases were discolored or killed. Later, a few of the plants made a fair growth considering their unfavorable start.

The plants in all tiles were harvested and weighed on December 2, and the weight per tile and also the average for each group are given in Table I. The tiles in group A, where the soil was alkaline, gave the highest yield, an average of 192 grams. Groups B and C gave yields of 176.8 and 166.4 grams respectively, showing a gradual decline in yield with the increase in acidity up to a concentration of pH 6. At the lower pH value, group D, the yields dropped to 96.9 grams, a decline of 41.9 per cent. The yields from the most acid group were so small as to be practically negligible. The results of the yields obtained on the field plats are somewhat similar to those secured in the tiles Plat one, which was treated with the largest amount of acid gave a pH value of 4.16 on the most acid part and 5.20 on a slight knoll from which part of the acid may have been washed by excessive rainfall which occurred during August.

The crop yield on this plat was 56 pounds, or only 37.7 per cent of that produced on Plat five which had a soil pH value of 7.07. The plants showed injury similar to that found on the very acid soils in the tiles in group E. Many plants died and those which survived grew slowly. Plats two and three with pH values of 4.6 and 4.9 gave yields of 89 and 96 pounds respectively, as compared with 161 pounds on plat five. Plat four, with an acidity of pH 6.0, yielded 142 pounds, which was only 11.8 per cent less than secured on the alkaline plat. This compares well with the tile experiment where

the crop yield from the soils with a pH value of 6.0 and 6.5 was 13.3 per cent less than on the alkaline soils. The data obtained indicate that maximum yields cannot be expected on acid soils, but that the acid tolerance is such that fairly satisfactory growth can be secured on soils with a hydrogen-ion concentration as high as 6.0 pH.

TABLE I.

Group Arrangement of Tiles According to Average pH Value

Tile Number	Group	pH value August, 1924	pH value November 1924	Average for Period	Crop yield per tile in grams	Average yield per tile in grams
3	A	8.36	8.09	8.22	182.5	—
2		7.65	7.25	7.45	190.0	—
4		7.86	6.8	7.33	203.5	192.0
5	B	7.44	6.55	6.99	163.0	—
6		6.84	6.36	6.60	190.5	176.8
8	C	6.93	6.04	6.49	158.0	—
9		6.85	5.9	6.38	176.5	—
7		6.8	5.79	6.30	193 5	—
11		6.39	6.09	6.24	120.0	—
12		6.50	6.03	6.27	181.0	—
13		6.20	6.04	6.12	167.5	—
14		6.11	6.00	6.06	168.0	—
10		6.34	5.68	6.01	167.0	166.4
1	D	6 07	5.38	5.72	74.0	—
16		5.79	5.65	5.72	108.0	—
17		5 75	5.55	5.65	93.0	—
15		5.73	5.5	5.62	112.5	96.9
19	E	5.48	4 95	5.22	71.0	—
20		5.24	5.08	5.16	45.0	—
21		4 81	4 87	4.84	25.0	—
18		4.61	4.52	4.57	8.0	—
23		4.44	4.54	4.49	2.0	—
22		4.35	4 60	4.48	25.0	—
24		4.28	4.50	4.39	5.5	25.9

RELATION OF HYDROGEN-ION CONCENTRATION TO LIME REQUIREMENT

It is necessary to know the relation of the pH value of a soil to its lime requirement if recommendations are to be made for decreasing the soil acidity on very acid soils to a point where spinach can be grown successfully. Literature abounds in methods for making lime requirement determinations. The quantitative methods by Jones (8) and by Veitch (16), and the qualitative devised by Truog (14) are the more commonly used. Hill (5) found a close agreement between the Jones and Veitch method when investigating the effect of green manure on soil acidity. Blair and Price (1) noticed that for the samples of Sassafras loam soil tested there was a fairly close correlation between the hydrogen-ion concentration of the soil extract and the lime requirement as determined by the Veitch method. Carleton (4) in investigations on certain Canadian soils found some correlation between the pH value and the lime requirement by the

Jones method on soils of the same type and wide variations between those of different types and origin. In studying the effect of fertilizer chemicals on soil reactions at the Rhode Island Station, Burgess (2) secured very close correlation between the hydrogen-ion concentration of the soil suspensions and the lime requirement determined by the Jones method.

Lime requirements of the upper six inches of soil in each of the tiles and field plats were determined by the Jones field method (4), and qualitative tests of acidity were made by the Truog (14) method.

There was a fairly close relationship between the pH value, the acidity as shown by the Truog test, and the lime requirement by the Jones method except where the soils were slightly below or above neutral. Near the neutral point the lime requirement is probably too high. This discrepancy was also noted by Carleton (4) in working with Quebec soils

The alkaline group gave an average lime requirement of 50 pounds of CaO per acre; the group between pH 6.5 and 7, 850 pounds per acre, and showed a very slight acid reaction with the Truog test; that between pH 6.0 and 6.5, 1370 pounds per acre and a slightly acid reaction by the Truog method; that between pH 5.5 and 6.0, 1480 pounds requirement and a medium acid Truog test; that from pH 5.0 to 5.5, 1630 pounds CaO requirement with a strongly acid Truog reaction At greater concentration than pH 5 all reactions by the Truog method showed very strongly acid and a maximum lime requirement, by the Jones method, of 3200 pounds CaO per acre.

In the field test plat one, with a value of pH 4.15, showed a lime requirement of 2340 pounds CaO per acre; plat two, pH 4.6, 1980 pounds; plat three, pH 4.9, 1800 pounds; plat four, pH 6.0, 1440 pounds; plat five, pH 7.07, 360 pounds. This agrees fairly closely with the readings secured from the soils in the tiles. Whether this correlation will hold on the different soil types on which spinach is grown in the Norfolk section is still open for further investigation.

Conclusions

There is apparently a very close correlation between the hydrogen-ion concentration of the soil solution and the germination and growth of spinach. A neutral or alkaline soil proved optimum for high percentage germination and growth. The hydrogen-ion concentration represented by pH 6.0 was the lower limit for satisfactory growth from a commercial standpoint. At this concentration, Norfolk loam and Norfolk gravelly loam showed a lime requirement between 1200 and 1500 pounds of CaO per acre by the Jones method, and a slightly acid-reaction by the Truog test.

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Results of Some Experiments in Pruning and Training Greenhouse Cucumbers

By H. W. Schneck, *Cornell University, Ithaca, N. Y.*

THE PRACTICE of pruning and training greenhouse grown cucumber vines is universally followed by growers as a means of facilitating greenhouse operations, increasing yields, and preventing disease development by avoiding crowding and shading. Successful greenhouse men, however, do not agree as to the best pruning method. In surveys made in the large vegetable forcing centers of the East and Middle West, it was found that two general systems of pruning greenhouse cucumber vines are used, the single stem

and the extension stem methods. There are many modifications of these two general methods, especially of the extention stem system, and there are several methods of supporting or training the vines with each system of pruning.

Object of Experiment

In order to throw some definite light upon this problem, an experiment was planned and conducted with cucumber plants grown in a commercial way in the greenhouses at Cornell University four different years, and was repeated with plants grown in large paraffined wooden boxes the fifth year in order to have better control of soil moisture conditions, and to allow for a more accurate study of root and top growth than is possible with plants grown commercially in ground beds. The object of these experiments was to determine the effect of the two general pruning methods upon the following factors with two of the most important types of greenhouse cucumbers.—Yield of fruit, earliness, size of fruit, grade of fruit, cost of production, vegetative growth of plant.

Methods of Pruning and Training

The cucumber is a monoecious plant, male and female organs being borne in separate flowers which develop in clusters in the axils of the leaves. On normal plants of greenhouse varieties both male and female flowers do not develop in the same cluster. On the main stem of the plant both male and female flowers may develop, although most of the flowers are males. A side shoot forms in the axil of each leaf, on the first node of which normally a female blossom, or blossoms, develop. Hundreds of counts have been made and in 95 per cent of cases, the first node on side shoots bears female flowers with greenhouse varieties. If this shoot is allowed to develop further, male blossoms normally develop on several succeeding nodes before another female blossom forms. If the plant is allowed to develop naturally it will form a great deal of vegetative growth for each fruit formed.

The two general methods of pruning, single stem and extension stem, were used in each experiment, although with the first four experiments conducted with plants grown in ground beds, two different methods of supporting or training the extension stem plants were used, namely, the A-trellis support and the overhead trellis or arbor support. The single stem plants were trained on an upright cord tied around the base of the plant and to an overhead wire six and one-half feet above the surface of the soil. Each side shoot on the main stem was allowed to develop out one node and was pruned off just beyond the first leaf at which a fruit or fruits developed. Sub-side shoots which developed at this node were pruned in a similar manner. When the main stem had developed about a foot above the overhead wire and began to topple over, it was pruned off.

The extension stem plants trained on the A-trellis were trained upon wires supported by A-shaped wooden supports with eight feet under the supports and one foot between supports. The supports were seven feet high. The main stem of the plant was allowed to develop to a height of three to three and one-half feet on the support and was then pruned off. This stimulated the development of strong side shoots which were allowed to develop to the top of the trellis. Each of the main side shoots was then pruned in a similar manner to a single stem pruned plant. In the overhead trellis, or arbor system of training, the main stem of the plant was supported on a cord, and carried to a trellis six and one-half feet above the surface of the soil, which trellis consisted of a series of wires eight inches apart. All the side shoots on the main stem were pruned off, to within eight or 10 inches of the trellis, and four of the strongest were allowed to develop and spread out on the trellis. The main stem was pinched back when it was a foot above the trellis and this caused the more rapid and vigorous growth of the side shoots. These were carried out about five or six nodes and pinched back. The sub-side shoots were then carried out three or four nodes and pruned, the object being to get the over-head trellis quickly covered with vegetative growth at this stage of the development of the plant. When the trellis was covered, the sub-side shoots developing on the trellis were cut beyond the first node or leaf. As the leaves on the main stem turned yellowish in color, they were removed leaving only the main stem below the trellis with all the fruit and foliage on the overhead trellis.

Only two systems of training, upright with single stem plants, and overhead trellis with extension stem plants, were used in the fifth experiment conducted with plants grown in large wooden boxes.

Plant Arrangement

In the first four experiments four rows of plants with each of the three methods of training were planted across the greenhouse with two varieties in each row. The two outer rows with each training system were not included in the experiment because light conditions on plants in these rows were not the same as on plants in the inner rows. The same spacings given plants by commercial greenhouse men with different methods were provided, 13 or 13½ square feet per plant with extension stem, and four or four and one-half square feet per plant with single stem plants. The data given are secured from four years' experiments.

The boxes used for plants grown in the fifth experiment were 14 inches square and 14 inches deep, and the inside of each box was coated with paraffin so as to make it water-tight. Seventy-eight pounds of air dried screened greenhouse soil was weighed into each box. It was found that by adding 20 per cent, or 15.6 pounds of this weight of water to the soil, it provided the proper moisture content for good growth of cucumber plants. The water content of the soil was kept constant throughout the period of growth, by

weighing the boxes with the soil in such a way as to avoid weighing the top growth. Early in the experiment water was added two or three times per week, later when the vines had made considerable growth it was added every other day, or every day. The boxes were arranged so that the plants would be spaced the same as when grown in commercial beds. The plants in the outer boxes on the ends of the rows were not included in securing data in order to have uniform light conditions on the experimental plants.

Effect of Method of Pruning on Yield

The total yield records are given on the basis of number and weight of fruits per plant and per 100 square feet. Extension stem plants were given a spacing of 12 and 13½ square feet per plant, and single stem plants were given a spacing of four and four and one-half square feet. These are spacings given under commercial greenhouse conditions. Extension stem plants produced an average of 30.5 fruits weighing 22 pounds per plant and 245 fruits weighing 182.6 pounds per 100 square feet. Single stem plants produced a lower yield per plant, 16.2 fruits weighing 12 pounds, but a greater yield per 100 square feet, 398.6 fruits weighing 267.4 pounds. These results are based on three years' experiments with a total of 103 extension stem and 128 single stem commercially grown plants. The influence of method of pruning has a pronounced effect on the yield secured, producing 46.9 per cent less in number and 45.3 per cent lower weight per plant, but 62.6 per cent greater number and 46.4 per cent greater weight per 100 square feet with single stem plants as compared to extension stem plants. With a short lived plant such as greenhouse grown cucumbers, where the plant does not build up a permanent supporting system, the yield per plant is not essential, but the yield per given area is the important factor to consider from the commercial standpoint. When considered in this light the single stem method of pruning which allows for close planting is the more desirable. This method of pruning permits a maximum amount of fruit development per unit of vine growth, and per unit of area occupied by the plant.

Effect of Method of Pruning on Earliness

Greenhouse grown cucumbers normally produce fruits for a period of from two and one-half to four months. In determining the period of harvest time to be considered as early yield, it was decided to call the yield secured during the first third of the bearing season each year as the early yield. This represents an average of four weeks for the three years for which the data are considered. With 43 extension stem plants, 26.5 per cent of the total yield produced was secured early, whereas with the same number of single stem plants, 40.6 per cent was secured early.

This probably is due to the fact that extension stem plants are pruned in such a way as to secure large vine growth before much fruit is allowed to develop, whereas, single stem plants are pruned

from the start for fruit development. Not only is the total yield per unit area greater, but the early yield is also greater where vine growth is limited by pruning. Earlier fruits bring higher prices on the markets.

Effect of Method of Pruning on Size of Fruit

The average weight of 1129 marketable fruits produced on 88 extension stem plants over a period of three years was 14.3 ounces. During one year records were kept on length and circumference of 313 marketable fruits from 45 plants, the average length was 11.6 inches and the average circumference was 7.5 inches. The average weight of 697 marketable fruits secured from 95 single stem plants over a period of three years was 12.2 ounces. The average length and circumference of 231 marketable fruits from 52 plants one year was 9.8 inches and 6.8 inches respectively. The method of pruning has a pronounced effect on the size of fruit, pruning for vine growth early in the development of the plant causes the development of 17.4 per cent longer, 9.6 per cent thicker and 16.8 per cent heavier fruits than are produced by a system of pruning which limits vine growth for the production of a large number of fruits early in the development of the plant.

Effect of Method of Pruning on Grade of Fruit

During two years of the experiment, all the marketable fruits were divided into two grades according to size and shape. All marketable fruits which were not straight and uniform in shape or small in size were considered as second grade fruits. With 1467 marketable fruits produced on 80 extension stem plants, 51 per cent were grade one and 49 per cent were grade two. With 652 fruits from 84 single stem plants, 42 per cent were grade one and 58 per cent were grade two. This indicates a slightly greater percentage of grade one fruits with large vine growth, but the total number of grade one fruits formed per unit area was greater with single stem plants because the total yield was greater. The greater percentage of grade one fruit with more vine growth on extension stem plants, probably is due to the fact that the fruits were of larger size, and there was a lower percentage of small fruits placed in grade two. The effect of method of pruning on the grade of fruit produced is not very pronounced, although more grade one fruits develop per unit area with close pruning than where more extensive vine growth is allowed to develop, the extensive vine growth producing a larger percentage of grade one fruits.

Effect of Method of Pruning on Cost of Production

During one year, accurate account was kept of the time required to prune 52 extension stem plants given 13¼ square feet per plant and 60 single stem plants given four and one-half square feet per plant.

Extension stem plants required a total of 23 minutes per plant and single stem plants required eight minutes per plant for pruning. Calculated on the unit of area basis, the time required per 100 square feet of ground covered was practically the same, 182 minutes for extension stem plants and 181 minutes for single stem plants. The cost of pruning per unit of area being the same, the increase in yield produced by single stem plants per unit area can be considered as net gain over yield produced by extension stem plants. Although the actual time required is the same, to prune extension stem plants correctly requires considerable more skill and knowledge of the plant's growth habit. Especially is this true early in the plant's development when the pruning is designed to secure proper vine growth. Pruning single stem plants is very simple and requires no particular skill or knowledge of the plant's habit of growth.

Effect of Method of Pruning on Vegetative Growth of Plant

The effect of the method of pruning on vine and root growth was studied with 15 extension stem and 15 single stem plants grown in boxes, spaced the same as when grown in ground beds. This study was made in order to determine the reasons for differences in fruit development secured in previous experiments. The prunings, which were secured every few days, were weighed, and at the close of the experiment the top growth of each plant was weighed and added to the total weight of prunings. The average total weight of vegetative top growth of the extension stem plants was 74.1 ounces per plant and of the single stem plants, 51.5 ounces per plant. The average total weight of root growth per plant at the close of the experiment was 9.4 ounces for the extension stem plants and 4.7 ounces for the single stem plants. With large top growth, a large root system is produced, but in limiting top growth the root system is limited to a proportionately greater extent than is the top growth. This may be partly due to the larger proportionate amount of fruit produced by the limited top growth in single stem plants which makes a greater drain on the elaborated plant foods, thus reducing the quantity available for root growth. Since the cucumber fruits are harvested before they mature from the standpoint of seed development, this drain upon the carbohydrates and proteins formed in the leaves is probably less than the drain of these materials where seed formation is completed as in tree fruits.

Since early fruits are not permitted to develop on extension stem plants, the food which is manufactured early in the growth of the plant is more largely used in the roots, whereas on single stem plants there is a constant drain from the start by the fruits upon food manufactured in the foliage which it would seem might account at least to some extent for the decrease in root growth.

The cucumber plant can be severely pruned. This allows closer planting when it is desired to secure a large early yield and total yield per unit of area, although the individual plant will not yield

as heavily nor produce as large fruits as will plants which develop more vegetative growth before fruit is allowed to form.

With extension stem plants, a larger part of the foliage of each plant is exposed to the direct sunlight than is the case with single stem plants, but with single stem plants it would seem that a larger proportion of the leaf area per plant is exposed to sufficient light for maximum photosynthesis, although the light intensity which most of the leaves receive is not as great. Since light intensity is not an important factor in relation to the rate of photosynthesis, but amount of leaf surface exposed to light is important, probably single stem plants, which receive light on both sides of the plant and on both surfaces of the leaves, would be at least as efficient in the manufacture of food per unit of top growth as the extension stem plants, although with extension stem plants there is more leaf area per plant. Thus the light factor cannot be an important one with reference to differences in vegetative and fruit growth produced.

Another factor involved in this connection is with reference to soil moisture. Although attempt was made to keep the soil moisture up to optimum with all the plants, after the first four weeks of growth extension stem plants always required more water than single stem plants in order to bring back the soil to the optimum moisture content. This indicates that the extension stem plants really had a lower soil moisture content throughout the experiment than single stem plants, which would also account in part at least for more extensive root growth proportionately with extension stem plants. Before each watering, the top growth with extension stem plants suffered somewhat more for want of water than single stem plants and thus did not make maximum growth for full utilization in the top growth of food made. Probably more of the food made in the extension stem leaves was thus available to the roots making for proportionately larger root growth.

Extension stem and single stem plants used exactly the same amount of water, 56 quarts or 112 pounds per plant, the first four weeks of growth, during which time an average of 12.7 ounces of fruit per plant were harvested from extension stem plants and 40 ounces per plant from single stem plants. The total amount of water consumed per plant was 164 quarts, or 328 pounds for extension stem plants which produced 4.8 pounds of fruit, and 125 quarts or 250 pounds per plant, for single stem plants which produced 5.6 pounds of fruit. The plants were removed from the boxes before they became root-bound, and were studied for top and root growth.

If the plants could have continued growth, the extension stem plants would probably have out-yielded the single stem plants as they did in previous experiments with plants in ground beds. There were many small fruits on the extension stem plants and only a few on the single stem plants when they were removed from the boxes. If the experiment could have been continued, the extension stem plants would probably have utilized a still larger quantity of water per plant.

TABLE I.

Effects of Extension Stem and Single Stem Methods of Pruning Greenhouse Cucumbers on Different Factors

	Extension Stem	Single Stem
Total Yield		
Per plant	30.5 fruits— 22.0 pounds	16.2 fruits— 12.0 pounds
Per 100 square feet. . .	245. " —182.6 "	398.6 " —267.4 "
Earliness		
Percentage of total yield secured first four weeks of harvest.	26.5 per cent	40.6 per cent
Size of Fruit		
Average weight per fruit .	14.3 ounces	12.2 ounces
Average length	11.6 inches	9.8 inches
Average circumference	7.5 "	6.8 "
Grade of Fruit		
Per cent of grade one.	51 per cent	42. per cent
Number grade one per 100 square feet.	125	167.4
Time Required for Pruning and Training		
Per plant. .	23 minutes	8 minutes
Per 100 square feet.	182 "	181 "
Vegetative Growth		
Top growth per plant. .	74.1 ounces	51.5 ounces
Root growth per plant.	9.4 "	4.7 "
Top growth per 100 square feet.	548.9 "	1144.4 "
Root growth per 100 square feet.	69.6 "	104.4 "
Weight of fruit per ounce of top growth.	1.1 "	1.7 "
Weight of root per ounce of top growth.	.13 "	.09 "

With extension stem plants, one ounce of top growth produced 1.1 ounces of fruit and .13 ounce root growth, and with single stem plants one ounce top growth produced 1.7 ounces of fruit and .09 ounce root growth. This indicates a larger proportion of fruit and smaller proportion of root growth per unit of top growth with single stem plants. At least one of the factors involved would seem to be the early fruiting of the plant which draws upon the plant food made in the leaves at the expense of root growth.

With a short-lived annual plant such as the cucumber, the effect of pruning on vegetative growth is not as important from the standpoint of food storage and the building up of a permanent supporting system as it is with long-lived fruit trees, provided sufficient vegetative growth is allowed, to produce a large yield of the size and type of fruit desired. In the greenhouse where soil fertility and moisture can be supplied in sufficient quantity to produce vigorous growth, the plant is capable of supporting a maximum amount of fruit per unit of vine.

If the cucumber plant had a different habit of growth and normally produced female flowers and fruits at every node, probably the extension stem system of pruning would be more desirable, considering that fewer plants would be required per given area. There is a possibility of developing a type of cucumber which has this characteristic, but thus far we have no such type.

Considering the individual plant, extension stem plants in ground beds, normally, produce a larger vegetative growth, greater total yield and more first grade fruits of larger size than do single stem plants. But when the problem is considered from the practical standpoint, the severe pruning of single stem plants permits of much closer planting, which makes the total yield, the early yield and the amount of first grade fruit per unit area greater with single stem plants than with extension stem plants. Table I gives the results of the extension stem and single stem methods of pruning greenhouse cucumbers.

Some Physiological Aspects of Asparagus Officinalis*

By VICTOR A. TIEDJENS, *Massachusetts Agricultural Experiment Station, Waltham, Mass.*

INTRODUCTORY

INDIVIDUAL records of 1170 asparagus plants were taken for four years in order to study individual plant performance in its relation to the vegetative propagation of the high yielding plants, so that a higher yielding strain of Martha Washington asparagus might be obtained. So far, reliable data have been secured on plant

*The data herein reported and utilized for publication by the writer are the result of a project on Martha Washington asparagus, originated and started by Professor H. F. Tompson, formerly in charge of the Market Garden Field Station, at Lexington, Mass., which is a department of the Massachusetts Agricultural College. The work was taken over by the writer in the spring of 1924.

performance, but very little study has been made of vegetative propagation. Such factors as the ratio of mature stalks to spears (tips cut in the spring as compared with the mature stalks in the fall), the consistency of bud formation, the effect of temperature on spear production, and the reliability of one year's results for judging the yielding power of a specific plant, have been studied. The ultimate objective of the project for which these data are being taken is to determine the most efficient method of improving asparagus for larger spears, earlier production, and uniformly higher yielding plants.

There are a number of theories that have to do with the performance of asparagus plants which are commonly accepted, but which are wanting in experimental evidence. It is hoped that these data may help to substantiate some of the theories accepted and possibly disprove others. It is also hoped to encourage further work on this plant which lends itself so well to fundamental research by the plant physiologist and geneticist.

Methods

In 1918, one-quarter acre was set to one year old Martha Washington roots, grown at the testing farm at Arlington, Virginia, in 1917, and selected by Professor J. B. Norton, formerly with the United States Department of Agriculture.

The soil is a fine sandy loam, considered fair for asparagus. The field was limed and fertilized with manure and mixed fertilizers in liberal quantities each year. The plants were set at 18 inch intervals in rows four feet apart. There were 26 rows, lettered alphabetically, and the plants were numbered from one to 45 in each row. All the roots grew. Early each spring the tops were harrowed into the ground. In 1920, the production of spears (†) was so large that some were cut, but unfortunately no records were kept of the plants. In 1921, the first records were kept and a large yield of spears was obtained. The spears recorded in classes, A, B, C, and D: A being spears one inch or over in diameter, B one-half to one inch in diameter, C less than one-half inch in diameter, and D either frozen or flat (fasciated) spears.

The cutting season is the period from the time growth starts until approximately July 5. A late season may extend this period one or two weeks. The length of cutting season for the four years was as follows:

Length of Cutting Season

1921	May	5	to	June	27—54 days
1922	"	6	"	"	20—46 days
1923	"	8	"	"	27—51 days
1924	"	14	"	"	30—47 days

Asparagus is a perennial plant whose early spring growth and production of marketable shoots depends on stored foods elaborated by the plant the previous season. This food material is made largely

†Shoots cut in the early season are designated as spears, and mature fall stalks as "stalks."

in the green tissue of the plant through photosynthesis and later stored in the crown and fleshy roots. All food material used in the growth of the spears must come from this reserve food. While this reserve food, which is largely carbohydrate (sugars) (2), and some protein material from the nitrogen compounds taken from the soil, is being stored, growth of the crown is taking place. There is no carbohydrate material stored as starch (2). The result of this growth is the formation of buds for the next season's crop. ·These facts must be kept in mind in dealing with various phenomena discussed later in this paper.

External Morphology

Before considering some of the phenomena shown by the data it is well to consider a few observations made on the plant itself, since much of the data has considerable bearing on this morphology.

When the seed germinates, the plumule produces a stem, and a few roots are formed from the caulicle. These small roots soon begin to thicken so that a root five centimeters long has a diameter of three millimeters. Secondary roots are formed on these which bring water and food material to the plant. Apparently food storage organs are started very early in the life of the plants, if these fleshy roots are the storage organs as is commonly supposed to be the case. Data later in the paper support this supposition. Seedlings which have had part of their tops broken off prematurely have roots smaller in diameter than those which mature normally, so that the weight of such a crown with its roots is proportionately lower. The roots formed on a three year old plant first appear as bud-like projections and grow out as storage organs in contrast to those formed on a seedling whose main function is to supply the plant with water. They are usually quite white in color and take on a brown color which is intensified from year to year. In the older plants secondary roots do not appear until the root has reached a considerable length. Roots have been found which were 10 centimeters long and five millimeters in diameter without a single secondary root.

In an old plant the large storage roots make up practically the entire root system of the plant. Occasionally long roots are found which are of a fibrous nature and covered with secondary roots. Many of the fleshy roots lose their entire content after a lapse of a few years. The length of life of these roots is not known, but probably depends on the demand for food to produce spears. They have been found on three year old plants. The roots usually spread out laterally but some go to quite a depth which is probably controlled by the type of subsoil. In a sandy soil the tendency is probably to go deeper. Since storage organs are usually found near the surface, it would be natural to expect to find them spread laterally rather than vertically as is the case where roots serve only as water conducting tissue.

The crown is largely of a woody nature and more or less of a rhizome from which the buds project. Growth takes place in certain definite directions. As is shown later, buds are formed as food

is stored in the subterranean part of the plant. In a seedling the buds are clustered more or less around the stems, the size diminishing from the stems to the periphery of the crown. In older plants the buds are formed at the periphery of the crown, thus extending the crown. There is a progressive development of buds as is shown by their size. The buds first appear as scales which soon fill out and can be easily counted. The first buds formed in many cases produce stalks the same year. Whether the number of buds agrees with the number of sprouts sent up the following year is still a question. The larger ones grow first, and those toward the periphery start to grow in order of their size. This fact has considerable bearing on the discussion of the relation of environment to time of appearance of the spears. It is interesting to know just what the condition is. Is there a definite interval between formation of bud and time of appearance of spear? What effect do available food supply and time of year have on time of spear appearance and size of spear produced?

In the case of a five year old asparagus plant disintegration takes place where the old stems have been removed so that we may find that a division has taken place and instead of one plant we may find two or three. The fleshy roots seem to be one year behind the buds. Buds are formed from storage material. The following season these buds produce stalks, and as a result of their food storage, fleshy roots make their appearance in that part of the crown in close proximity to the stalks. The crown acts as a rhizome to transport the food reserves to the buds.

Observations on 45 plants on which a record had been kept showed the staminate crown to be larger than the pistillate crown. Also, the staminate plants had more numerous buds, but they were not so large as those of the pistillate plants. That staminate plants produce more buds, but smaller ones are shown by the data. The average bud production for the staminate plants is 23, 24, 21, 24, respectively, for the four years, while the pistillate plants produced 17, 15, 14, 15, respectively, for the four years. The pisti late plants show a general decline while the staminate plants held up quite uniformly.

On May 1, 1924, 45 roots were dug for propagation work. They were all examined for bud development and extent of root system. Parts of the crown showing four to seven buds had not sent up a single spear, but had been either so starved as to prevent growth, or had been attacked by some parasite that killed them. A decay of the central part of the crown where spears had been cut had separated many of the plants into two to five units. This may have caused the starvation of the buds described above.

In cultivating the field in the spring many of the plants were so near the surface that the disc harrow dug into the crowns and broke off some of the buds. This was unfortunate for the experiment, but it was not noticed until it was too late. This together with the buds which failed to grow due to decay or starvation would vary the figures for individual plants and may account for those plants that had one year of the four low in number of buds. It may also account

for the fact that the plants divide due to disintegration of the central portion of the crown where spears are cut off. These separate units would then act as single plants and we would expect the number of buds to increase during the later years. Such a plant is shown by M-5 where the number of buds was 51, 49, 55, 90. When total buds are mentioned it simply means those which appeared above ground as spears plus matured stalks.

The data reveal plants having eight mature fall stalks and only producing one spear the following year. Also plants with only one mature fall stalk produced 20 spears the following year. There are examples of all possible gradations between these. A correlation table does not tell the whole story. The fall count was taken regardless of the size or age of the stalks The asparagus plant continues to send up shoots throughout the season. If one mature stalk is present it probably was sent up in July directly after the cutting season. Where eight or 10 stalks are present they may have been sent up one at a time from July to October. It could hardly be expected that a stalk sent up in September would store as much food reserve as a stalk sent up in July. There is also a decided difference in size of stalk Are small stalks one-half inch in diameter by two feet high able to store as much food as stalks one inch in diameter by four feet high? The longer time required to grow the larger stalk together with the greater amount of food used to grow it may make up the difference. The length of cutting season likewise would influence the number of spears as compared to mature stalks. The number of mature fall stalks varies considerably even though total number of buds remains fairly constant. It is possible to select examples for a correlation for or against it depending on the point of view developed.

Bud Development and Spear Production

There is some controversy as to whether latent buds in the asparagus plant are formed adventitiously or whether they are formed the season previous to the time they make their appearance as spears. In a large plant, from which spears have been cut, the buds can be easily seen and counted when it becomes dormant in the fall. These buds are sent up throughout the following year as spears. The spears making their appearance above ground during the "cutting season" are removed, while those coming up after the cutting season form mature stalks which elaborate the food material for the following season's crop. Whether the end of the cutting season is the beginning of bud formation is a question. It seems possible to suppose that growth of the crown takes place before this storage process begins. If so, it must do so at the expense of the stored food, which may or may not curtail spear production, depending on the amount of food available. In seedlings certain buds can almost be called adventitious as they grow up to produce the later stalks after the plumule has sent up the main stem. Whether this is also true in older plants is still a question.

The Relation of Food Reserves to Spear Production

What, then, is the explanation for the production of buds, and later, stalks in the asparagus plant? To be sure a plant must send up shoots to reproduce itself, but this does not explain certain characteristic plant performances shown by the data. Whether these are purely physiological, or are caused by heritable factors, cannot be definitely shown, but the data suggest several possibilities.

The number of spears cut and the length of the cutting season are arbitrarily determined by the season, the market price, and the time available. Certain fundamental principles in regard to effect of fall growth on spear production the following season, should be of much value to the market asparagus grower. Is it advisable for him to discontinue cutting spears when the market price is low and thus force the plants to produce more spears the following season to compensate for the low cash returns he receives?

It was stated that spear production is dependent on the stored food reserves in the crown and roots of the plants. Waters (3) has shown the need of having the corm of the timothy plant well stored with food reserves in order to insure a heavy yield of timothy the following year, and permanence of the crop. Nelson (4) has shown the need of stored food reserves in the root to insure a big crop of alfalfa the following cutting or season. Both papers bring out the fact that the plants are very susceptible to injury and are easily killed when food reserves are stored too sparingly in the plants the previous season. In view of these facts the number of mature fall stalks was correlated with the number of buds produced the following season. Correlation figures for the four years show the correlation, between mature fall stalks and buds the following year, to be higher for the staminate than for the pistillate plants. In the pistillate plants the correlation is not very significant, (.2436, .2647, .2311, .3074, respectively, for the four years). During the second and third years, there is a fair degree of correlation for the staminate plants, (.3056, .4389, .5284, .3067). Just how much emphasis we can place on this correlation is a question. If the number of buds produced by a plant is determined by the amount of reserve food stored by the mature stalks the previous season, we would expect individual plants to vary from year to year in the number of buds produced. We would expect plants to increase their number of buds from year to year until the first cutting season is reached, after which we would expect a sharp decline because fewer buds will grow into mature stalks to store food reserves. The data do not indicate this. There is a decided uniformity in number of buds produced from year to year.

The effect of spring fertilization on spear production may be worth some discussion. Does temperature have an effect in making nitrification more rapid? If we accept the theory (5) (6) (7) that nitrates cannot be utilized by the plants until chlorophyl is present, and there is considerable evidence supporting this theory, then we would not expect the application of nitrates in the spring to have any influence

on the production of spears that season. Brooks and Morse (8) have shown this to be a fact. Nitrates, however, are necessary for the production of nitrogen reserve products built up by the plant later in the season for the following season's crop. Thus the nitrogen and carbohydrate material for the production of spears must all come from the roots.

The correlations show that as the number of mature stalks increases, the number of spears the following year increases. There are various factors that might control or change this correlation. The shoots, supposedly, are not adventitious, but are formed the previous season at the time the food reserves are being stored in the roots. Whether all the sprouts sent up in a given year are the result of buds formed the previous year, is a supposition as much disputed as that all the buds of a given year will develop into sprouts the following year. The uniformity of bud production from year to year, as shown by the data, offers some light on the subject and also suggests some internal factor at work If the amount of food stored does not support all the buds, some of them will not develop into stalks while others will produce small spindly stalks which produce very little storage material, but are counted as mature fall stalks. These late stalks in many cases would draw on the reserves rather than add to them. Plants that have 40 buds and produce 30 spears during the cutting season would offset those having 40 buds which produce only 10 spears during the cutting season There would remain 10 and 30 buds respectively to store food for the following year's crop. If 10 mature stalks store food and collectively are responsible for 40 buds the following year, 30 mature stalks should be responsible for three times 40, or 120 buds This, apparently, is not the case, as is shown by the correlation figures How are we to explain plants producing 20 or more mature fall stalks and only one spear? They are late maturing plants that escape the cutting season, and yet do not produce any more spears the following season as a result of all the food reserves stored. The correlation is almost exactly the same, whether we take only the spears or the total number of buds. Consequently there are as many early maturing plants as those that escape the cutting season due to late maturity. The number of buds, then, does not seem to be determined by the amount of food reserves stored.

What, then, is the significance of the correlation figures? By manipulation during the cutting season these plants may be shown to have almost any correlation, and the ratio of fall stalks to spears may vary from 10:1 to 1:10 depending on time of maturity and length of cutting season. The figures do prove the fallacy of reasoning that the extent of bud production is dependent on the amount of reserve foods stored in the plant. To be sure, food material is necessary to develop these buds normally, but other factors seem to be responsible for determining the number the plant shall produce. It is hoped to prove this by means of vegetative propagation of the crown and then checking up to see whether the daughter plants have as many buds as the parent plants possessed. The fact that we

find one year old seedlings with from three to 40 buds lends support to the idea of a genetic controlling factor at work. The time of formation of these buds must then be the season previous to the time they form spears. More exacting research may show that the buds are formed throughout the season and that a few of the early ones may produce stalks the same year, depending on freezing weather and whether a certain rest period is necessary before the buds can start to grow. Perhaps growth may be more or less continuous and amount of food storage determines when the spears make their appearance. Observation shows that at least the majority of buds are formed the previous season That is the time crown extension and new storage root development take place, and if certain internal factors are responsible for bud formation it is not begging the question to say buds also are formed. That is the time any perennial plant prepares itself for the following season's performance. If buds were formed the same season that the spears are produced, we would not expect to see so many abnormally small stems during the season, which apparently are latent buds developing under adverse food conditions. If the buds were adventitious, one would expect only tissue containing sufficient food reserves to support normal growth to send out stem tissues. The uniformity of production of buds from year to year; the fact that there is no direct ratio of fall stalks to number of buds produced; that seedlings have as many buds as older plants; and that root and crown growth takes place the previous season all lead us to conclude that bud formation takes place the season previous to the time of spear production and that the number of buds is determined by some internal factor other than amount of reserve food stored. Some of the data may indicate otherwise but that is the exception rather than the rule in view of controlling environmental factors that would account for such performances.

Causes of Plants Dying Each Year

It is not uncommon for a certain number of asparagus plants to die each year, the cause of which is not always evident. Records taken show the greatest mortality to be among the staminate or male plants The year 1922 showed over nine per cent dead among the staminate plants while none was noted among the pistillate plants until 1923 when only two and one-half per cent were found to be dead. Several suggestions can be offered for this dying among the plants of either sex.

A study of plant performance for the four years showed that a number of plants found dead had produced spears, but no mature stalks, the previous season. As has been suggested, each plant has a certain number of buds formed and if all these buds are activated during the cutting season none remains to grow into mature stalks so that food for the following season's crop may be stored. In a plant that produces only three or four buds this is evident. When a plant which ordinarily produces more buds so that sprouts may be sent up during the summer behaves this way, it is possible that the

reserve food material has been exhausted for the early shoots, and the buds did not produce late summer sprouts because of a lack of energy in the roots and crown to feed them. There is a question whether any reserve food material left after all the buds are removed as spears, can be utilized by the plant for the following season's crop of buds, and if so whether there will be sufficient reserve material to activate these buds.

When a plant has produced a number of mature stalks and does not produce spears the following season, death in many cases can be accounted for by a pathogenic condition, such as a slow root rotting fungus setting in where spears have been cut and a wound has been made in the tender tissue. This may likewise account for plants which show a decline in number of spears from year to year. Freezing conditions during the winter may account for some of the dead plants where observation does not show any other causes. Why staminate plants die in greater numbers cannot be definitely answered. It is true that staminate plants are bigger yielders by as much as 30 per cent as is shown in the data. They grow more rapidly, are usually the first to send up shoots, and are produced in greater numbers from a given lot of seed so that there may be a natural tendency for the plants to be less resistant. This dying of the staminate plants in greater numbers is significant in view of the fact that they are the larger producers

Quality of Spears Produced

The number of cuttings was less in 1922, 1923, and 1924, than in 1921. The duration of the cutting season likewise was less during the last three years. The type of spears produced varied from year to year, probably being dependent on the range of temperature as warm weather makes growth more rapid In 1924 the season was exceptionally cold, so that growth was slower and the spears were larger. Thus the percentage of A, B, and C spears was practically the same for 1921 and 1924, but varied considerably in 1922 and 1923. There is a question whether size of spears (diameter) is dependent on temperature or heredity. The data do not answer the question. Pistillate plants did produce a larger number of A and B spears consistently for the four years, as is shown by a comparison of the individual plant records. Thus when the staminate plants produced a large number of spears, the pistillate plants produced larger spears and the sum total in weight is probably very nearly the same. This, of course, requires more detailed experimentation for conclusive proof. Apparently high spear production is not correlated with large spear production. Seed production in pistillate plants may account for the difference by demanding a different metabolism and structure in the plant.

Factors Affecting Shoot Growth

The relation of temperature to shoot development was plotted. How can temperature affect the growth of shoots? A certain temperature is necessary to start growth in the buds. When the plants

are eight inches below the soil, it is a question how much effect a fluctuating temperature may have. These plants varied in the depth of crown below the surface. A crown four inches below the surface may be in a warmer medium than those at eight inches. The one at four inches would start to grow first, and it would be called an early plant. It is possible that plants may vary in their response to a given temperature. Just how much emphasis can be placed on the figure is a question. It has been shown that the rate of growth increases with an increase in temperature. This would lead us to expect that growth through the soil would be more or less regular because growth takes place in the tip of the shoot. When the tip reaches the surface, growth may be very irregular due to the fluctuating temperature. This accounts for the erratic growth found during the cutting season. Spears may grow to the surface and stop until a higher temperature (a warm day) is available. This would result in a number of spears coming from the plant on a warm day, when as a matter of fact they had been growing up to the surface for several days.

Morse (9) has shown that a large amount of sugar is stored in the roots and crown late in the fall. It is probably used in this same form when the buds begin to grow. Apparently there is no change from the time it is made in the leaves until it is used in spear growth the following spring, except that part which goes to make new tissue and is changed to pentosans, cellulose, and lignified cellulose in the crown and roots

The main function of temperature seems to be to build up tissue in individual shoots. Whether there is an increase in number of spears during the season as temperature increases, or whether the buds grow up at certain intervals (temperature of course to be sufficiently high for growth) regardless of an increase in temperature, cannot be proven by the data. Whether an exceptionally and uniformly high temperature during the cutting season produces more spears than a lower temperature is to be questioned. The plant undoubtedly is protected against such a performance which would send up all its buds during the early part of the year thus endangering itself by having those buds all removed as spears during the cutting season.

The relation of temperature to size of spear was also studied. Female or pistillate plants have been shown to produce larger spears. Also some staminate or male plants produce uniformly larger spears than others. There is an advantage for the grower in having large spears because fewer are required to fill a bunch. Is size of spear dependent on temperature or hereditary factors? Some evidence available shows that plants bred for high production and increased vigor have numerous large spears. Professor J. B. Norton (10), in his bulletin on Asparagus Breeding shows a high positive correlation between size of seed and height of seedling, between height of seedling and cross section of stalk the following season, and between size of cross section of stalk and diameter of spear the following season. However, this does not eliminate the effect of temperature unless the correlation can be shown for a successive number of years under

varying degrees of temperature. These correlations indicate a genetic influence which determines size of stalk.

SIGNIFICANCE OF VEGETATIVE PROPAGATION

In view of the foregoing discussion, what can we expect to accomplish through vegetative propagation? The number of cuttings that can be obtained from a root is determined by the number of buds on the crown. If a plant has 40 buds we should get 40 single stem plants. Because of the close proximity of some of the buds, it will be impossible to make 40 cuttings. May we expect the 40 plants to grow and in three years produce approximately 40 buds each so that we would be getting 1600 buds from the original? Why should we expect this any more than we should expect the plant to increase in number of buds from year to year? An answer to the question on inhibitory factors will answer this. By cutting the crown into separate pieces, new units are produced which should act as the parent plant. Inhibitory factors could be said to be partially eliminated and the unit allowed to develop into a plant like the parent. The size of cutting to make will be determined by the length of time in which a bed is expected. Small cuttings will take more time than large cuttings. If it is true that these buds develop throughout the season regardless of inhibitory factors, the bed set to cuttings would be very irregular. The cuttings would not send out a stem when conditions are most favorable for their growth, but would send them out as the season advanced. The first plants would be able to store much food for a vigorous growth while other plants coming up late in the fall would starve or winter kill. This fact will determine whether a method of vegetative propagation ever will be a commercial success.

CONCLUSIONS

1. Staminate plants die out sooner than pistillate plants.

2. Dying out of plants in many cases is due to too vigorous cutting of the spears so that no fall stalks are matured.

3. Staminate plants are higher producing by 25 per cent, and hold up better from year to year.

4. Pistillate plants produce a greater percentage of "A" (large) spears.

5. There is a positive correlation between the number of mature fall stalks and the number of buds produced the following season. Staminate plants are again superior in this, due probably to the fact that seed production exhausts some of the strength of the pistillate plants.

6. There is a decided uniformity in number of buds produced from year to year in a large number of plants, suggesting a genetic determining factor.

7. Inhibitory factors may have some influence on time of growth of spears which develop from buds in close proximity.

8. Buds apparently are formed the season previous to that in which they develop into spears. The size of spears and number developing are undoubtedly influenced by food reserves stored the previous season.

9. Although temperature does not seem to affect the time of appearance of the spears, it does affect the rate of growth of spears.

10. The number of plants that can be secured from a parent crown by cuttings will be determined by the position and number of buds on the crown.

11. The number of spears cut may or may not determine the production of a plant the following season, but enough spears must be allowed to mature so that sufficient food reserve can be stored for the following season's crop.

12. Allowing all the spears to mature would not necessarily increase the number of spears the following year.

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Northern-Neck Virginia Tomato Demonstrations

By A. G. Smith, *Virginia Polytechnic Institute, Blacksburg, Va.*

EARLY tomatoes are shipped as green wraps from only one section of Virginia. This area lies in the lower part of the Northern Neck, between the Rappahannock and Potomac rivers. The nearest railroad is 80 miles from the early tomato belt. However, several small rivers and tidewater creeks, flowing into the Potomac, provide

deep water landings within a few miles of all the tomato growers. The freight service on boats plying on these rivers has proved very unsatisfactory, not only on account of the schedules, but because Washington and Baltimore are the only markets reached.

Green-wrap tomatoes have been shipped from this section for more than 25 years. During this period the production of green tomatoes in other states has developed steadily in sections with adequate rail transportation, while the returns from this crop in Virginia have gradually decreased. In spite of all this, some of the Northern Neck farmers have continued to produce green tomatoes, but have made their living largely from the fish and oyster business which can be carried on in the winter and spring seasons.

In 1922, the Extension Division made a survey of a part of the early tomato belt. It was found that the most serious problem was that of transportation and marketing, yet many practices followed in the production and preparation of the fruit for market were in need of improvement

The annual shipment ranged from 50,000 to 60,000 six-basket crates. All were packed in the fields in second hand containers. None of the fruit was graded and none of it wrapped. In this condition it was hauled to the nearest wharf and sold to buyers on the spot or in some cases consigned to commission houses. The greater part of it was purchased by men who carried it across the bay to Crisfield, Maryland, where it was graded, wrapped and packed in new crates. The remainder of the crop went on boats to Baltimore or Washington.

Under this plan the prices at local wharfs stood at about $3.00 per crate for a few days and then dropped more or less rapidly to 50 cents per crate, when deliveries to local canneries began. The average shipping season lasted from 10 to 15 days.

At the request of the growers a general plan was outlined and submitted to them at a meeting called for the purpose. It was suggested that they form a marketing committee to handle the tomatoes from a limited number of farms on a cooperative basis the following year. A simple contract form was provided by the Extension Division. Twenty growers along Coan River bound themselves together under this temporary agreement and selected a marketing committee of three from among themselves.

This committee purchased 11,000 new crates, neat lables, wrapping paper and other supplies. At the beginning of the harvest season, representatives from the Extension Division and the State Bureau of Markets spent a week there assisting this group.

A fish shed adjoining a canning house was equipped as a demonstration packing house, and a group of local packers was trained. The fruit was trucked from the shed to the wharf where it was loaded on boats bound for Baltimore.

The first load shipped netted the growers a good margin above prices paid on local wharfs, and the central packing shed was operated until the market dropped.

This demonstration convinced the more thoughtful growers that if the same plan were extended to include the entire, or greater part of the crop, they would be able to market their fruit with a much greater profit than they had ever received in the past.

As the cull fruit was thrown out at the demonstration packing shed, growers, who looked on, realized for the first time that they had been packing and shipping crates which contained a high percentage of inferior tomatoes, and further that they had in reality been paying for the cost of hauling this fruit across the bay and having it graded and repacked.

General Organization

Before the close of the shipping season a county agent was employed. Through his efforts a canvass was made among the tomato growers and a general sentiment favoring cooperative marketing was found. Accordingly, it was decided to undertake a campaign for the formation of a cooperative marketing association among the tomato growers.

In order to establish this on a sound basis, the specialist conferred with the State Bureau of Markets and the Department of Agricultural Economics. After going over the situation, as it had developed to that time, the following plan was decided upon:

First: to call meetings in the several communities to discuss the possibilities of organization.

Second: That a plan of organization be prepared by the Extension Division including contract, legal forms, etc.

Third: The appointment of a temporary organization committee.

Fourth: Two general meetings to pass upon organization plan as prepared.

Fifth: An intensive farm to farm campaign to be conducted by the organization committee, assisted by the county agent, and specialists.

Sixth: Frequent meetings of organization committee for reports and discussions.

Seventh: Preparation of articles for papers, circulars, etc.

Eighth: Meetings to be held at each shipping point or local to nominate directors.

Ninth: Election of all directors at a general meeting.

Tenth. Meetings of directors and employment of manager.

Since this project had been started and handled by the Vegetable Specialist, it was decided that all letters and literature pertaining to this organization be sent through his office. This "clearing house" idea worked effectively and from the point of view of the growers all information received by them came as a recommendation of the Agricultural College rather than as suggestions from three separate departments.

The plan as outlined was followed in every particular. Before the expiration of the time limit set by the organization committee, approximately 60 per cent of the tomato growers had signed a three

year contract. Under the contract the member is required to deliver all green tomatoes at some association packing house for cooperative marketing.

The association took the name Coan River Tomato Association, Cooperative, and was incorporated under the cooperative law of Virginia.

With a membership of 175 representing about 300 acres at the time of incorporation, the association now has 225 members with almost double the acreage controlled at first. The total acreage produced in the section has not been materially increased.

The directors employed a competent manager and under his direction the association has completed a very successful season. Five central packing houses were operated this year. A boss-packer was contracted with on a per crate basis and 25 experienced packers handled the fruit.

The association employed a sales manager to distribute the tomatoes, much of which was government inspected when loaded.

During the present year more than 30,000 crates were shipped under the "Coreta" brand The crop was unusually short. Due to the careful manner in which the fruit was handled and distributed, the association was able to get good prices through a 30-day period. As mentioned before the average shipping season under the old plan was about two weeks.

The officers of the association made every effort to get the river boat companies to give them service across the bay to Crisfield, but were finally forced to charter their own boat. The service rendered by this boat was excellent and cost about $10,000 less than the same service had been quoted by the boat company operating the regular river boats.

A local of the Farm Bureau is established in the Coan River tomato belt and has been the means of contact between the extension workers and the people. Almost all of the tomato growers are members of this farm bureau.

Variety and Wilt Demonstration

Bonny Best and the old Earliana varieties have been used in the Northern Neck for years. It was noticed that the crops on some farms were almost a total loss because of rough fruit. Fusarium wilt is generally distributed in the section and causes heavy losses in the later harvests.

In 1923, several demonstration plots were conducted without any striking results. In 1924, six wilt resistant varieties distributed by Dr. Pritchard of the Bureau of Plant Industry at Washington, were planted. Only one, Marvelosa, seemed promising. Some seed were saved from this and the variety will be planted in larger areas next year.

The Extension Division has made a special effort to bring about more uniformity in the type of fruit produced by the association members. Recently they voted unanimously to eliminate every-

thing but Bonny Best this season and use enough Livingston Globe to give it a thorough trial. All the seed are being ordered by the manager, definite orders having been placed for more than 100 pounds of selected seed. This should go far toward bringing about the desired uniformity of the fruit.

During the past season demonstrations were conducted in plant bed management, transplanting and fertilizers.

Conclusion

The demonstration with the Northern Neck tomato growers serves as an example of effective extension work. The policy of our Extension Division is to form cooperative bodies only where such organizations are considered essential.

We do not consider the formation of an association the end in itself, but as a means to an end. In this instance it has served as the entering wedge for extension work into a very important but isolated section of the state.

It has provided the growers with the means of handling their own problems. Transportation troubles that have baffled them for a generation as individuals, were solved in a single season by this group.

Through the association the growers will be able to standardize their green tomatoes and learn to appreciate the fact that a high quality product is the foundation of successful marketing.

The Extension Division now has a means of direct contact with these growers and has their full confidence. With such a beginning the constantly recurring problems connected with seed, varieties, insect and disease control, fertilizers, and soil building, can be dealt with in an effective manner. Ten years of extension work with individuals would have seen less accomplished than has been done through this association in one season.

We do not believe that a large membership alone can make an association successful. It is rather the enthusiasm and zeal the members show in its support that make it worth while. No association, regardless of its size, is stronger than its leadership. In this instance the Extension Division saw that the best men in the section were placed at its head.

Similar problems in other states may be solved in the same general manner. The important thing is to so thoroughly analyze the field that every problem will stand out clearly and be sure that the plan offered for its solution contains nothing but sound remedies. The next logical move is to point out step by step the many turns of the road that will lead to a more general prosperity. This is the substance of demonstration work.

Development of a Spray Service for Virginia

By F. A. Motz, *Virginia Polytechnic Institute, Blacksburg, Va.*

NOTWITHSTANDING the fact that fruit growers meetings, spraying demonstrations, spray notices, press articles, etc., played an important part in the season's work, the loss of fruit from insect and disease injury seemed to be on the increase. In the fall of 1922, after carefully checking up the yields following the harvest season, a startling fact was revealed That 48 per cent of the total apple crop in Virginia was sold to by-products plants while but 52 per cent was barreled and sold as No. 1 and No. 2 fruit. The spray recommendations which were given out early in the season seemed to be adequate, as good results were secured in demonstration orchards which were supervised by the horticultural specialist, and in a few individual orchards which were equipped with adequate machinery and where the spray program was carried out. The fruit in the state experimental plats showed a loss of less than 10 per cent, caused by preventable parasites, most of which could have been included with the 90 per cent of good fruit and have passed state inspection. In spite of these facts, it was plainly to be seen that we were not reaching the growers, as a class, and it was quite evident that the methods employed were ineffective Having reached this conclusion, means were devised whereby the methods already in use could be supplemented with something which would appeal to the growers and produce results As the fruit industry of the state is made up of several thousands of growers, it was necessary that the masses be reached, rather than just a few individuals, if Virginia expected to maintain her position, horticulturally, and withstand successfully competition from other fruit growing districts

The formation of fruit growers organizations seemed to be the most favorable avenue through which the growers could be approached and this, with the cooperation of the State Horticultural Society and the staff of horticultural workers, could be made possible. Such organizations were formed and it is through them that the service is functioning today.

The first great need was to secure reliable field data regarding the development of certain economic parasites which were threatening the industry. With the acquirement of such data and the experience of past seasons, together with information secured through fruit growers organizations and individual growers, it was thought that a spray service could be built which would not only be effective, but popular with the growers.

With this plan in mind the service was developed. Through negotiations with the Experiment Station and Crop Pest Commission, arrangements were made to locate field laboratories and research men in the most important producing sections, and to extend these stations as far as funds would permit. The field laboratories were located at Winchester, Crozet, Lynchburg and Blacksburg. The

points selected were well distributed, geographically, and were representative of the different growing conditions found in the state. Life history studies were made chiefly in connection with insect pests and fungous diseases affecting the apple and peach, and which are amenable to spray treatment. It is the function of these stations to provide information, during the progress of the work, to the committee in charge at Blacksburg, the same being transmitted to the grower through his local organization and utilized at once.

Early in the spring of 1923, a series of conferences was held with county agents and leading fruit growers to outline a policy for distributing the spray service information and to perfect the agencies through which the service could be properly handled. Through these agencies a fruit growers' mailing list was prepared, made up of some 2,500 producers of fruit. A spray bulletin, entitled "Orchard Spraying in Virginia -1923," was prepared and distributed. The bulletin contained condensed spray tables for all pomological fruits grown in the state, giving number of sprays, materials to use, time of application, parasites involved, etc., the information to be supplemented by the reports sent in from the field laboratories.

The data secured by the field laboratories were sent into Blacksburg and received the consideration of the Departments of Plant Pathology, Entomology and Horticulture. After recommendations were agreed upon by these departments, the information was transmitted through telegraphic service to the organizations designated to disseminate the information to the growers in their district whose names appeared on the mailing list. The county agents were previously supplied with franked cards which were addressed and prepared in full for mailing. The date and signature were left blank. These cards were held in reserve by the county agent or authorized party, and when notices were received from the central office the dates were filled in, signatures supplied, and the cards mailed out to his members or growers.

The card prepared for each spray called attention to the number of the spray which corresponded with that contained in the calendar; the date of application; material to use, and for what purpose intended. Due to the sectional differences in the state, the time of application varies widely. This is due to elevation, exposure, soil and location. In giving out the dates of application, careful consideration had to be given to these facts so that there would be no conflict between the date of application and the stage of blossom or fruit development in the particular locality called for. The sprays had to be timed as accurately as possible because the information, after leaving the central office, would be in the hands of the grower within a period of 24 hours.

Results

The results of the year, compared to those of the previous one, were in a general way very satisfactory. Many letters were received from county agents and fruit growers commenting favorably on the

service rendered. It also opened up lines of future development pertaining to good orchard practices.

The service revealed to the grower many weaknesses in his plan of orchard management, namely, inadequate and inefficient machinery, lack of thoroughness of application, insufficient spray material per tree, use of untested material and the limit of application extended over too long a period The use of the spray service brought these points so forcibly to the attention of the grower that many new high power spray outfits were purchased and more spray material and hydrometers used than ever before. The average number of sprays was increased from approximately three to five and one-half and in most instances they were applied with more thoroughness and timed more accurately.

After completing a survey of 1923 conditions, and making a check on the practicability of the service, plans were made for developing the service for the coming year. At the beginning of the season, 1924, several conferences were held similar to those called before, resulting in certain modifications of the service as used during the preceding season It was decided that definite dates would not be given for the delayed dormant, pink and calyx sprays, but that stage of bud, blossom or fruit development would be used instead As cited earlier in the report, the wide range of climatic conditions caused such a wide variation in development of growth between different sections, or even within a limited district or county, that the dates recommended were often improperly timed and spraying in some instances had already begun before the notices reached the grower, or the stage of development at the time of the date specified did not warrant an application for possibly three or four days to a week later. Dates for the 10-day and following sprays, however, were given, and were more accurate and effective than the dates given out for the same sprays in previous seasons.

The mailing list at the beginning of the year contained over 3,000 names. It increased steadily during the season and at the present time consists of about 4,500 growers County agents and growers organizations are very much interested in keeping their mailing lists up to date. After each notice is sent out there is invariably a request from the county agent to add additional names, or to make corrections in their previous list. They ask that these names be added before the next notice is sent out so that their members will be sure to get the benefit of the service. Additional cards are sent along with each lot that goes out to be used by the agents in case of emergency. These cards are, of course, filled out but are not addressed. At least 35,000 notices were mailed out during the year and in addition, news articles appeared in all the papers calling attention to the control measures recommended at that time. By this method we were able to reach all the fruit people in the state either directly or indirectly. The notices kept the county agent before his growers during the entire season and demonstrated to them that he was on the job and trying to serve his county to the best of his ability.

The increased percentage of low grade fruit of 1924 over 1923 would appear to create some unfavorable comment. On the surface it would not seem to appear so favorable to the spray service work. The increased percentage of low grade fruits, however, is by no means a fair indication or test of the value of the spray calendar or the spray service. Weather conditions, which enter so largely into good production, were decidedly unfavorable for the development of first-class fruits. A prolonged rainy season during the spring and early summer months prevented the growers from carrying out an effective spray program In some instances it was impossible to apply a spray within as much as two weeks after the recommended date. The growers were prepared to put on a complete spraying program and plans were outlined early in the season to carry it out as far as possible. In many instances, sprays were applied between showers and the ground became so soft that the spray machines became mired. Some growers, becoming desperate after waiting two or three weeks for favorable spraying weather, resorted to dusting. Notwithstanding these unfortunate conditions, some growers estimate that less than 40 per cent of the total commercial crop was thrown out. This seems exceedingly large, but this percentage takes into consideration hail pecks and cedar rust, which were unusually severe this season, and are not amenable to spray treatment. Hail injury occurred at different times in practically all districts of the state and were it not for this factor, the percentage of No. 1 and No. 2 stock would have been considerably larger. Cedar rust in some sections also caused tremendous losses. This is being gradually eliminated, however, by an unceasing effort on the part of the scientific workers advising the growers in the matter of cedar eradication.

Before attempting to revise the calendar which was used the past season and before making definite recommendations for 1925, a questionnaire was prepared and mailed to all county agents and leading fruit growers asking for criticisms of the present system and for suggestions for the development of a bigger and better spray service. About 75 per cent of the questionnaires were returned and the written statements from the sources named indicate that the service is about as accurate as can be expected. Many growers expressed themselves that it is one of the outstanding pieces of extension work. The more intelligent and successful growers approve of the recommendations as sent out the past season and fully appreciate the fact that it is impossible to lay down hard and fast rules governing all conditions.

Forty-five hundred fruit growers, representing the third largest apple producing state, are being benefitted directly through this type of service. A large number of small growers are receiving benefits through information passed on by their neighbor or through the local newspapers.

Field surveys and letters show a large percentage of the growers are making an effort to carry out better spray methods.

Results in packed fruit indicate a direct ratio to the closeness which the spray program was carried out.

Many additional standard spray outfits have been purchased.

Method of application has improved and the testing of material in concentrated and dilute form has increased.

A striking demonstration of what proper spraying will do under adverse weather conditions was brought out

The college and extension workers were brought before the people and a closer contact between them established.

Sending out notices periodically keeps the grower reminded at all times of the type of service the State and Federal Governments are attempting to render. It prompts the grower to call upon the state representative for information dealing with subjects other than spraying which lead up to economical production.

Plan of Work Proposed for the 1925 Spray Service

As a result of the questionnaire which was sent out containing suggestions from those closely in touch with field conditions and possessing an intimate knowledge of their local problems, some modifications will be made in the new spray calendar.

Instead of giving definite divisions of the fruit growing areas of the state in the calendar, a procedure followed in 1922 and 1923, each card mailed in 1925 to these sections will contain specific information for that particular section, thus eliminating some slight confusion on the part of the growers.

No dates of application will be given for the pre-pink, pink and calyx sprays, but attention will be called to the stage of development and emphasizing the importance to the grower of exercising his common sense as applied to the stage of development of the bud or blossom. Dates for the later sprays will be given as has been the custom in the past. In addition to the number of the spray, its use, materials to use, etc., attention will be called to such essentials as proper dilution, thoroughness of application, power, etc.

The calendar will contain a table giving dates of application for the various parasites and the dates of first appearance of various fungous diseases and insect pests for the period covering the past three years. This should aid the grower materially in planning his work and will serve as a guide for the approximate dates upon which these various sprays should be applied.

An effort will be made to keep in closer touch with growers located in sections removed from the field laboratories so that a check can be made as to the accuracy of our recommendations as applied to their local conditions. This has been suggested by the growers themselves and no difficulty should be encountered in getting prompt reports from these men.

Summary

In conclusion, permit me to call your attention to the fact that the Virginia Spray Service is one of the most important factors in the successful operation of an apple raising business which ranks third in the United States. Since so much money is involved, and realizing the importance of correct recommendations and the ne-

cessity of an efficient broadcasting agency, we have built an organization in Virginia which works successfully and has the confidence of the growers. In the evolution of this spray service it was found necessary to make alterations from year to year as experience and research pointed the way Probably the scheme of the Virginia Spray Service would not work in a state like New York or Washington because of different local conditions. It is essential in the development of this spray service that close observance to the status of fungous diseases and insect pests, together with a consideration of differences in elevation and topography of a state, be given.

In view of the fact that the greatest service any state extension department can render its apple growers is to furnish them with correct information about spray applications, materials, etc., it becomes of paramount importance that the scientific facts governing these recommendations must be obtained by a complete cooperation between the departments of Plant Pathology, Entomology, Horticulture and the Extension Service It must have scientific facts before broadcasting any information. With such a foundation to work on it is possible to build a successful spray service in any fruit growing section of the United States

Some Individual Reports of Home Orchards

By G. H. Firor, *University of Georgia, Athens, Ga.*

GEORGIA is recognized as the largest shipper of fresh peaches in the Union, shipping this past season 13,120 cars, and during 1923 the total cars shipped were 8,701, which is by no means a small shipment. A ten-thousand-car crop has always been looked upon as a very large crop for this state. The past season's peach crop was harvested from 12,000,000 trees During the past three years, 3,200,000 peach trees have been planted in the state which have not come into bearing, 1,000,000 of which will come into bearing this next season for the first time

At the present time the peach crop consists of the following varieties with the per cent of each given. Early Rose 3.2; Carman 7.1; Hiley 31.3; Belle 6 4; Elberta 51.9. This enormous crop of fruit was distributed to the markets of 308 cities.

At one time the peach industry of Georgia was localized in two or more centers, but to-day it has developed to such an extent, due to the advent of the boll weevil, that it covers a very large portion of Georgia and is not confining itself to any one section of the state.

Another fruit industry of importance is apple production, which confines itself to the mountain section of North Georgia. The growing of apples was started by a lone pioneer in 1896. A few years later this industry started to grow very rapidly, and in 1908 a large crop of fruit was harvested. This section of the state is adapted to the growing of apples and the expansion of commercial production

of apples is looked for, as there is an untold area of land that is still in the virgin condition.

The increase of plantings of the commercial fruits of Georgia is due to the development of the home orchards A goodly number of the successful orchards today started out on a small basis of a few acres. Seeing its possibilities, the orchardists soon developed them on a larger scale.

During the year 1912 13 the horticultural specialist established home orchards along the A. B. & A Railroad that runs from northwest central to southwest central Georgia. These home orchards were established in 10 counties, over a distance of 150 miles. At that time there were only a few commercial peach orchards along that railroad and they were poorly cared for. Spraying was practically unknown and pruning very seldom practised either in the commercial or home orchards This past season 780 cars of fruit were shipped from the A. B. & A. Railroad sidings

It is the object of the extension specialist in horticulture to train the county agents through demonstrations of seasonal nature. Our method of operations follows.

(A). Three or four home orchards are established in a county where there is an agent who is interested along this line We do not force our work on men who do not care to take it up These orchards are used as demonstration centers where pruning, spraying, cultivating, fertilizing and the like are shown to groups of interested people.

(B). The following year these home orchards are visited and additional meetings are held in the county and new demonstrations are established and spray rings are often formed.

(C) The third year a campaign program is organized and, through the cooperation of the county agent, a number of meetings are held throughout the county for the purpose of establishing a county wide program of home orchards. The county agent is the principal factor acting as instructor, with the specialist simply as an advisor to him, visiting the county as often as necessary and advisable to help the agent, who by this time is thoroughly familiar with all of the seasonable orchard operations Such a method permits the specialist to give instruction to several new county agents annually and to still feel that the work in the older counties maintains its maximum efficiency.

As an illustration a certain county agent spent two years in a county under the instruction of the specialist in the development of home orchards. During his third year, 1923–24, he was transferred to another county in the state. The first year he established 100 home orchards without special assistance, 65 of which completed their projects successfully. He has for his goal 500 home orchards in that county. Spray rings are already established and 17 barrels of winter spray material purchased: 14 new barrel spray outfits have already gone into the county this season. This is one year's work.

I wish to cite a few instances where home orchards have been outstanding this past season in spite of the fact that we produced an unusual crop of fruit, especially peaches. While the chief pur-

pose of the home orchard should be the supplying of fruit for home needs, yet the profit to be derived from a well kept orchard is by no means to be despised. The commercial production of peaches and apples has been developed to a great extent, but yet there is a very good demand for various kinds of fruits on the local markets, even in cities surrounded by commercial orchards.

A home orchard demonstration center in DeKalb County was established with J. S. Jackson during the early fall of 1922, using peaches and apples as the central commodity.

The results of this work show that Mr. Jackson's sales in 1924 were as follows:

From 400 one-year, 80 three-year and 10 fifteen-year old peach trees	$165.00
From 22 forty-year old apple trees	337.50
Total	$502.50

The cost of producing this crop was $17.90, which gives Mr. Jackson a monetary net return of $484.60.

Another home orchard demonstration center was established with Mr. O. T. Adams of Clarke County during the winter of 1920. During 1924, throughout the spring and summer, practically no rot nor worms were present.

The results of this work show that Mr. Adams' sales in 1924 were as follows:

From 133 peach trees, 520 crates	$710.60
From 50 grape vines	61.58
From 12 plum trees	22.50
From 2 apple trees	7.30
Total	$801.98

A demonstration apple orchard of 109 trees belonging to J. W. Casper of Barrow County produced from sales $500. The cost of producing this crop was $99.75, which gave him a monetary net return of $400.25.

Our reports, this season, would permit our extending these examples indefinitely. Quite a number of these reports have found their way into city and county agricultural papers, thereby increasing the interest in the work. Each successful home orchardist is also a booster. We are, therefore, anticipating a greater demand for assistance next season than we will be able to accommodate.

Spread of Influence of Fruit Extension Work in New York

By JOSEPH OSKAMP, *Cornell University, Ithaca, N. Y.*

THIS paper presents an analysis of data pertaining to fruit farme which were collected in a larger field study conducted by ths Federal Office of Cooperative Extension work and the Extension Service of the New York State College of Agriculture in cooperation.* The purpose of the study was to determine the extent to which rural people have been influenced by cooperative extension work to modify farm and home practices. The data were collected by extension workers making personal calls at every farm in the community selected and interviewing the farmer and his wife. The information so secured was recorded on individual questionnaire cards.

THE AREA SURVEYED

This particular discussion relates to the Brockport and Spencerport Communities in Monroe County which is an important fruit section typical of a large area in Western New Work. Active extension work began with the employment of a county agent in 1913. The territory is considered a prosperous farming section three-fourths of the farms being on concrete or other improved roads and within half an hour by automobile of the city of Rochester. However, the area surveyed by no means included the best and most progressive townships in the county, nor the poorest The area was selected with the idea of being about average. If anything, it was probably somewhat below average

While fruit represents in most cases an important part of the farm income, it is seldom, if ever, grown exclusively. In fact the orchards are small, often varying from eight to 15 acres on a general farm. Apples largely predominate, although cherries, peaches, pears, plums, quinces and some small fruits are grown. Many of the apple orchards are old.

CONDITIONS AT TIME OF SURVEY

From the standpoint of getting the most favorable reaction from the farmers, a more unpropitious year could scarcely have been chosen for the work. At the time of making the survey in May, 1924, apples were being taken from storage and hauled to the dry house or cider mill. Much of this fruit had been stored tree run in the fall due to the failure of buyers to take hold, which forced growers to either store or ship on consignment. Consignments were generally a slaughter. The market never recovered, except for a brief period in March when exporters saw an opportunity for profit.

The generally unsatisfactory apple deal together with continued high taxes and a very unfavorable spring for orchard work was sufficient to account for the widespread dissatisfaction among farmers.

*The Effectiveness of Extension Work in Reaching Rural People, by M. C. Wilson and D. J. Crosby (In mimeographed form; to be published as a bulletin).

But the general agricultural depression served to further aggravate the situation.

Limitations of Study

Here we have a county effectively organized for the conduct of extension work. A county that has had an agent for the past ten years, has had its community committeemen, executive committeemen, community project leaders, county project leaders, and has had available from the College the usual help and service of specialists. What is there to show for this work? Is there anything tangible? Despite this survey that has been made and the actual figures recorded there is a feeling that many of the changes and benefits that have come about as the result of organized extension work are intangible and very difficult if not often impossible of measurement What person, for instance, when suddenly approached can mention the practices he has changed and the particular agency that influenced him to change the practices. Many simply do not know. There are those, too, and their number is not small who come to believe in a very short time that the new practice originated with themselves, and are not inclined to give credit to any outside influence.

The difficulty of the problem does not render the need of some form of measurement any the less insistent and should not discourage effort in that direction. It should be realized, however, that our methods of measuring the response of a human being are imperfect and the figures fall short of the actual truth to that extent.

Attitude Toward Extension Work

There are a total of 522 farms in the adjoining communities of Brockport and Spencerport. Records were secured from 513 farms, or 98 per cent Of these 395, or 77 per cent, were fruit farms, that is, farms on which fruit was a commercial crop. This further indicates the importance of the area as a fruit section. The average size of all farms was 90 acres, while the average size of fruit farms was 88 acres. It was to be expected that the fruit farm might be somewhat smaller. Of course the difference would be even more marked between *general* farms and *fruit* farms; the above figures for all farms include the 77 per cent of fruit farms.

The membership in the farm bureau is interesting and might be variously interpreted. Thirty-two per cent of all farms were present members of the farm bureau, while 39 per cent had been former members only. This condition is probably healthy, but nevertheless not entirely satisfactory. The effect of the agricultural depression on the attitude of the farmer has already been suggested. Here we have a concrete example of his reaction. The raising of membership dues in the county farm bureau at this time from three to five dollars was doubly hard to bear. The rather low present membership, therefore, is probably not to be interpreted as a reflection on the county farm bureau, but is the natural result of economic stress.

While the fruit farmers were hard hit, they were either better able to stand the strain, were more optimistic or believed they were getting a valuable service, for fruit farms showed a membership of 38 per cent present and 36 per cent past. It should be understood in all figures that "all farms" include the very high proportion of 77 per cent fruit farms which serves to minimize the percentage differences

The attitude of the fruit farmers was also more favorable to the farm bureau, and extension work, 56 per cent of all farms being favorable to extension work and 68 per cent of fruit farms favorable. The small number of seven per cent was opposed in each case to the extension work

Practices Changed

Changed practices give one an insight into the spread of influence of extension work In this survey 77 per cent of all farms reported one or more practices changed, while 87 per cent of fruit farms, reported changes in fruit practice This seems to indicate a worth while achievement for the extension work and the efforts of the extension workers seem not to have been in vain

Not unexpected to those who have had experience in fruit work is the high percentage of fruit farms reporting changed practices in spraying, 76 per cent being the figure in this case. As we all realize there is probably no orchard practice which has such a large, immediate and universal influence on the income of the orchard as spraying and the grower has sensed this.

Fruit farms reporting changed practices in pruning are 25 per cent, and the smallness of this figure is not unexpected. The most notable changes in pruning recommendations that have come about in recent years as a result of investigation, have to do with the young tree. There are comparatively few young orchards in New York State.

The farms reporting changed practices in soil management or fertilization are also low, nine per cent. The day of the argument over sod versus tillage is past Most of the orchards in Western New York are tilled and in this particular area probably 80 per cent are tilled. While this transition from sod to tillage had its inception in the early research work and extension teaching of the college, yet the farmer now comes to look upon it as common knowledge, which he always possessed. The outstanding change that has developed in more recent years is the use of a nitrogenous fertilizer in sod orchards. As there are relatively few sod orchards, changes in this respect are not numerous. The cultivated orchard under New York conditions does not ordinarily respond to fertilization.

Observations indicate that many minor changes in practice have come about in recent years, but the grower is likely to overlook them unless specifically questioned about each. Earlier cultivation would be one of these. Special inquiry did not cover this point.

Response to Extension Methods

The particular teaching method which influenced the change in practice is generally the most obscure and difficult to determine of any factor. If an appreciable time has elapsed since the change in practice the farmer himself does not often know what influenced him. Very often there are many contributing causes.

It seems that changed practices in pruning were largely traceable to demonstrations. In pruning, 25 per cent of the fruit farms reported demonstrations as influencing change in practice.

The extension school was credited with having caused a change in practice on 29 fruit farms or seven per cent of the fruit farms. Not all the farms, however, came within the influence of a school. Five extension schools having fruit as a part of the program were held in the town of Brockport during the past eight years and the total enrollment numbered 204 people. The town of Brockport is centrally located in the community and would be easily accessible to the 273 fruit farms in this community. Of the total roll of 204 people, many were repeaters from year to year and hence do not represent new contacts. Also some of those enrolled were juniors and hired men and not farm owners, and the survey is on the basis of farms. But ignoring these factors, let us assume that extension schools reached 200 farms in this community. Of the 29 fruit farms reporting change of practice as the result of extension schools, all were in the Brockport area and attended one or more of these five schools. On this basis approximately 15 per cent of the fruit farms attending an extension school were influenced by its teachings to the extent of changing a practice. This appears to be a rather low efficiency for the extension school. The figure closely approaches the 14 per cent reported as the influence from community meetings which is a similar method of teaching and might be expected to have similar results.

One of the outstanding features of the survey was the large number of farms reporting changed practice in spraying. Most of these changes were influenced by the spray service,—the figure being 62 per cent of the fruit farms. In some cases other methods were contributory.

The spray service it should be understood is available to the members of the farm bureau in the county and is carried on generally by a special field assistant to the county agricultural agent supervised by the departments of entomology and plant pathology. The spray information is based on actual observations in so-called criterion orchards in the county, as to the seasonal development of insects and diseases. This in conjunction with weather forecasts and the stage of advancement of the trees enables the field man to send out warnings for each spray. These are generally relayed over the telephone and confirmed by circular letter. Thus this comes very near to being a personal service. While there may be some theoretical objection to the idea of giving a service (used in this restricted sense) to the farmers, yet it surely appears to be an effective way of

bringing about change in practice. In fact with many farmers the spray service is the reason for their belonging to the farm bureau.

Then there are those men who will not join the farm bureau, but who are anxious enough to profit by the spray service. This can be done. It is common observation that when a member of the spray service gets out his spray rig, one or more of his neighbors who are not members often follow his example. The most progressive men are the first to take advantage of extension work. About 70 per cent of all farms reporting changed practices in Monroe County were influenced more or less indirectly—they imitated others.

Summary

This analysis includes 513 farms or 98 per cent of all the farms in one typical fruit area in Western New York. Of these farms 395 or 77 per cent were fruit farms. Present members of farm bureau on all farms 32 per cent, former members of farm bureau on all farms 39 per cent. In the case of fruit farms, 38 per cent were present members of the farm bureau, while 36 per cent were former members only.

Farm Survey of the Results of Extension Work in Monroe County, N. Y.

Item	Number	Per cent
Farms from which records were secured.	513	98
Fruit farms of record.	395	77
Average size of all farms (acres)	90	—
Average size of fruit farms (acres)	88	—
Present members of farm bureau on all farms	162	32
Present members of farm bureau on fruit farms	148	38
Former members of farm bureau on all farms.	198	39
Former members of farm bureau on fruit farms	143	36
All farms favorable to extension work	287	56
Fruit farms favorable to extension work	270	68
All farms opposed to extension work	39	7
Fruit farms opposed to extension work	28	7
All farms on which agricultural practices had been changed	395	77
Fruit farms on which fruit practices had been changed	343	87
Fruit farms reporting changed practices in spraying	301	76
Fruit farms reporting changed practices in pruning	97	25
Fruit farms reporting changed practices in soil management or fertilization	35	9
Fruit farms reporting demonstrations as influencing change in practice.	97	25
Fruit farms reporting extension schools as influencing change in practice	29	7
Fruit farms reporting community meetings as influencing change in practice	56	14
Fruit farms reporting spray service as influencing change in practice	244	62

Of all farms 56 per cent were favorable to extension work, while 68 per cent of the fruit farms were favorable.

A total of 395 farms or 77 per cent reported changed practices, while 343 fruit farms or 87 per cent of the fruit farms reported

changed fruit practices. These consisted primarily of changed practices in spraying—76 per cent, changed practices in pruning 25 per cent and changed practices in soil management and fertilization nine per cent.

The per cent of fruit farms reporting the following extension methods as influencing change in practice were: demonstrations 25 per cent, extension schools seven per cent, community meetings 14 per cent, spray service 62 per cent.

The Development of Landscape Extension Work

By F. L. MULFORD, *United States Department of Agriculture, Washington, D. C.*

THE OBJECT of extension work is to improve living conditions for the farmer and his family. Landscape extension work differs in no way from the general object. To be effective it must reach the largest possible number of farms in the communities where the work is undertaken. The purpose of this paper is to call attention to some of the means of securing results along these lines.

That attractive home surroundings tend to increase satisfaction with farm life is so well recognized by extension workers it seems unnecessary to demonstrate it here. Its recognition by farm families is not so widespread nor the hold that the idea has on the farming population is not so well known. Failure to improve farm home surroundings is probably due more frequently to lack of knowledge of how to proceed or a feeling that it is too difficult an undertaking, than from lack of interest, as many an agent and specialist has found more sentiment along these lines than he has had time to crystalize into effective action. The desire for help is so widespread that many agents and specialists, as well as the United States Department of Agriculture, have to be extremely cautious as to any announcements that are given as to the character of services that may be rendered in order not to be overrun with requests for aid which it is impossible to fulfill.

We may open the discussion then with the assumption that there is some demand for help and that the first duty is to work out an effective method of getting the assistance needed to those in the field who want it. What shall be the goal? A home here and there that is fully developed from the landscape viewpoint or many homes striving for better surroundings? Possibly the best answer can come from other branches of extension work. What is the object in fruit work, a better orchard here and there successfully reaching a fancy trâde or a general bettering of orchard practices and marketing throughout the fruit region? What is the object in poultry work, the establishment of a poultry farm here and there that succeeds in getting a specially high class trade or the improvement of the poultry

products of the community as a whole? What is the object of the canning club work, to make it possible for the girl or woman to compete at the county fair or on the open market with her products, or to improve the standard of living of the family throughout the year? What is the object of the boy's club work, to raise a better calf or a better pig than some one else, or to make a man who can use hand and head together?

From these analogies it would seem that the object should be to reach as many homes in a community as possible, that the county extension agent was on the right track who tried to have as many of her club women as possible do something about the foundations of their homes, no matter what work the club to which she belonged was doing, and that state has the right goal which is giving an extra credit of 5 per cent to every girl that successfully grows some flowers, no matter what work her regular club is doing.

If then the reaching of the largest number of homes possible is the goal the next problem is the method by which it shall be done. Some states make complete plans for home grounds in various communities and assist in carrying the plantings to completion, others use school grounds or other semi-public buildings, others work through community contests and so on through a long list. All of these things are valuable if used as a means of educating agents or for inspiring interest either in agents or the communities, but should be avoided as an end in themselves The most important factor in getting results are the county agents, but unfortunately there is frequently a tendency to overlook the work that can be accomplished whether by a farm demonstration agent or a home demonstration agent. Often a specialist expends a major effort on developing a demonstration, that is a completely planted home or semi-public building, and a minimum of effort on helping the agent to carry the message to other homes in the community where help is needed.

A specialist can reach but few homes directly through specific demonstrations, but many homes indirectly through the help of agents, hence methods need to be developed whereby the most help possible can be passed through the agents to those whom it is desired to reach. Naturally the place to begin is at an agent's district or state meeting depending upon the administration's plan for the development of the project. In at least one state it has worked well to divide the agents into groups according to experience and previous training and give each group instruction in the principles of landscape design suited to their needs at times as much as two hours a day for five consecutive days. Such a training with appropriate helps prepared by the specialist, supplemented by help in the field should enable agents who have developed their work to the point of being ready for home ground improvement to go forward with a real message for their county.

Such training would not develop the ability to prepare a complete landscape plan as would be expected of the specialist after his years of training, but should make possible the proper location of trees about homes on the plains where lack of shade is the most glaring

lack, or shrubs about the foundations of homes in the eastern United States where foundation planting is needed in spite of most of the homes having many fine trees and a large proportion of them too many, and even the location of approach roads and auto turns where serious grading problems are not involved. With lists of suitable plant material in hand the agent should be able to help solve most of the planting problems that would be likely to arise. Naturally the instructions to the agents should be made as simple as possible so that the work will not look too complicated and difficult or there will be hesitancy to undertake it.

Like other lines of work this is not likely to be taken up until it is included in the county program of work. When this is done there would naturally be enough interest so that a specialist would be warranted spending a little time in the county helping the agent get confidence to advise cooperators on details of their problems.

In connection with such a plan demonstrations are certainly helpful. Such demonstrations should be centered about the farm home. It is often advisable to include schools, churches or other public or semi-public buildings in the plan, but never without there being one or more farm homes included in the same community. It is seldom that members of a community will interpret plantings made at a public building in terms of their own home, but if homes are done at the same time the public building may serve as a general advertisement and inspiration and the demonstrations at the homes will call direct attention to the application. A demonstration is a failure if it does not inspire others to try and do likewise or serve as an object of study and instruction to agents. As a rule the more modest the home the more effective the demonstration. No plans should be made that do not definitely fit into a well considered program of procedure, otherwise it degenerates into a mere personal service and gives landscape architects reasonable grounds for objecting to the work. Mississippi has carried forward a definite plan of work for the last five years with demonstrations at the present time in more than half the counties of the state with 3203 homes about which improvement plantings were made in 1922, and 5488 in 1923, making it eighth in the number of homes reached in 1922 and third in 1923. In North Carolina where training of the home demonstration agents along these lines has been consistently and persistently followed for the past six years the number of homes reached in 1922 was 4622 and in 1923 it was 5799, making it third among the states in the number of homes reached in 1922 and second in 1923.

Experience seems to indicate that home ground improvement most naturally comes after demonstration work has been well organized in a county and has demonstrated its value to the community. It is closely associated wth the betterment of home conditions and has made the greatest progress in those states where Home Demonstration work has been fully developed. Kitchen improvement contests seem to create a desire for similar competitions on the home grounds and seem to offer conditions for satisfactorily introducing

the work. Both Virginia and Texas have counties in which successful large scale yard competitions are partially completed.

Where home demonstration work is well organized this often seems the most logical contact by which to create interest in such improvement as usually the women are quicker to see the possibilites and to respond to them and make an effort to get results. They are more hampered in such work than in many phases of home inprovement without the active interest and help of the men of the family. Many farm demonstration agents have done excellent work in getting home grounds improved but there is nothing so effective as real team work between the farm demonstration agent and the home demonstration agent along these lines.

Progress is probably most sure by following the methods used in other lines of extension work, that is picking out one of the most glaring needs of the homes of the community and stressing that for a year or more and then selecting some other point for improvement. In states where shade trees are lacking that is the best place to begin. Other good points to take up successively are foundation plantings, screen plantings, lawn border plantings, road relocation so that visitors and the family too naturally come to an appropriate entrance door instead of the kitchen door Sometimes this last will require an alteration of the house in order to provide such a door in a usable location. As a part of this or as a later development is the provision of an auto turn so that callers may turn and return to the highway without entering the service yard or farm work yard to do it. Many will not wish to follow the work this far so the easiest and most generally applicable improvement should be stressed first and as members of a community are ready, additional points can be added.

In the drawing of planting plans for demonstrators there has been a marked tendency to follow the practices of the offices of members of the American Institute of Landscape Architects instead of developing short cut methods better adapted to the needs of extension work. Few specialists have the time to develop a nicely finished plan on tracing cloth with the corresponding blue prints if some phase of his work is not to suffer from lack of attention and often it is this plan that is delayed because of the time it will take Prof. McCall, formerly of North Carolina developed a very useful short cut to relieve the necessity of so much labor being devoted to the making of plans. He provided himself with a folding drawing board on which by the use of carbon papers he could draw three plans at once. He also provided mimeographed planting lists for the diffierent sections of the state with the different plants numbered in the usual fashion of landscape architects. When plans for work had been developed in a community with demonstrations arranged at two or three farms and at one or two public or semi-public buildings he visited the proposed demonstrations, drew the plans while he was there, indicating the plants to be used. left a copy with each demonstrator and the county agent under whose leadership the work was being done and sent one back to his office. As Mr. McCall describes them the plans are too crude to be permitted to leave the office of a landscape

architect, yet they contained the information that the cooperator and the agent needed and were ready while enthusiasm for the project was at its height and in many cases where native plants were to be used resulted in the planting being started the following day. A crude sketch made in the presence of the demonstrator is apt to be more useful than a finished one from the headquarters office.

Tennessee has found the campaign to "Name your Home," which included the placing of the name in a suitable manner so the public could see it, resulted in much demand for help in improving the home surroundings as those who named their homes did not want to do it without the surroundings were attractive. Home ground improvement has been found useful in connection with boys and girls club work even though lacking in the element of profit usually found in the work. West Virginia has found community scoring an incentive to the improvement of home surroundings.

To summarize then the most far reaching results are likely to be obtained by pulling the landscape problems to pieces, giving it to prepared agents and communities in parts, using demonstrations only when conditions are well prepared and for a specific purpose and never where it may be interpreted as personal service either to an individual or a community not prepared to fully respond.

Standardizing Virginia Apples as a Means of Developing Markets

By F. A. MOTZ, *Virginia Polytechnic Institute, Blacksburg, Va.*

THE APPLE standardization project, which was so successful the past year, was made possible only by the ability and untiring efforts of the fruit standardization specialist of the State Division of Markets. Although it is an extension project in the true sense of the word, it was conducted cooperatively with the Division of Markets.

Efforts of the horticultural workers in the past have been confined largely to matters pertaining to better production, with the hope that ultimately standardization could be secured. As a first step, various means were devised to secure standardization of our apples into well recognized and approved grades. Community packing was the main idea. It seemed that better packing facilities, such as housing, machinery, trained labor and closer personal supervision, would in a large measure bring this about.

In 1922, a county fruit growers' association was perfected in Frederick County. The object of the members affiliating themselves with this association was to cooperate more closely along lines of better production, uniform grading and packing, and uniform selling. During this year approximately 32,000 standardized barrels received state inspection, which was the first time inspection had been tried

in the state. A state committee on standards was appointed to work with the interstate committee to study the common interests and see if a plan of operation mutually beneficial might be developed. This committee, in conference wth the marketing specialist of the Bureau of Agricultural Economics, Washington, agreed upon a set of grading rules or specifications to be adopted and used by states represented at this conference. The standards adopted were nearly identical with the grades prepared for Virginia in 1922.

The experience of the 1922 season brought out the fact that the state apple standards were misused to some extent and, to eliminate these conditions, the following year arrangements were made with the State Division of Markets to employ inspectors during the packing season to see that the grades were properly interpreted and carried out. This was done at a small cost, which was paid on a package basis by the growers receiving the inspection service.

As with the spray service three years ago, so it was with the inspection and standardization work; we were reaching a very limited number of growers and the quality of the pack was not improving to any appreciable extent. The Division of Markets wished to extend its field of operation and the actual inspection was to be directly under its charge, but the organization of the rings was to come under the head of extension work. We were to cooperate with the Division of Markets in arranging inspection and grading demonstrations and to urge the members of our community packing houses to join inspection circles, so as to keep their grade and pack up to the specified quality.

The project was in reality one of marketing as apparently there was no chance to effect a widespread cooperative marketing organization, due to the adverse sentiment of the grower for this type of organization.

In 1923, the work in Frederick County increased and approximately 69,000 barrels were inspected. The fruit from this district, however, failed to reach the southern markets, and the South is considered the logical place to concentrate our efforts along the lines of market expansion.

The standardization project was based upon the following facts:

1. That the loss of the Virginia barrel trade in the South can be charged almost directly and entirely to the poor business methods practiced by the Virginia growers.

2. That our methods of grading and packing are obsolete and unsatisfactory, and do not satisfy the trade.

3. That we have not kept pace with the progress made in marketing methods.

4. That the market standard for a No. 1 apple has changed in the last few years, due to the superior technique of our western competitors.

5. That the average Virginia pack was not uniform, poorly graded, and carried with it no guarantee of dependability.

The result is the loss of prestige and a decline in the sale of Virginia apples.

It was not until the beginning of the present year (1924) that a united effort was made to attempt a standardization project covering the state, and it was not until this year that the movement went forward with any degree of success. As the South offers good transportation facilities, short shipping distances, and a knowledge and demand for varieties with the consumer, it is natural that the grower should look to this section as the logical outlet for his fruit. During recent years, however, the demand for Virginia apples in the South, as well as in other markets, has rapidly decreased. The situation became so grave that buyers no longer continued to come into this territory to purchase their supplies and there was little call from markets which had formerly been supplied with Virginia stock. The growers seemed to be unfamiliar with the situation and could not understand for what reasons their product was discriminated against. It created considerable consternation among the more progressive growers and they asked that an investigation be made to determine why there should be a curtailment of their markets and why the product being shipped from Virginia should be discriminated against. The growers realized that the South is but one of her markets and the factors which were limiting sales there would surely become operative in other markets with the same effect unless they were removed.

In order to verify the supposed reasons and to secure intelligent answers to the statements just mentioned, the Extension Division, at the request of the members of the State Horticultural Society and other growers, was asked to make a study of the conditions which were influencing the sale of Virginia apples and if necessary to visit these markets with the object of gathering firsthand information from the dealers, to get a definite understanding as to the factors that were limiting the sales, and to devise means which would lead to a re-establishment of the trade relations which once existed between producer and distributor, and which would lead to increased sales of Virginia apples on this market.

Method of Procedure

The first step was to prepare an outline in the form of a questionnaire containing data concerning the dealers and which could be shown to the growers. A survey was made in most of the principal cities in the southern states which were representative of conditions existing throughout the South. Reliable wholesale and retail dealers were interviewed in all cities visited and the information obtained from them was set down on this specially prepared form. Questions were asked, such as preference of grades, varieties, containers, quantities used, and conditions under which they would purchase Virginia apples. Along with this survey, a study was made to determine the condition and quality of our apples on their markets, the ratio of Virginia apples to apples produced in other sections, why they were discriminated against, methods employed in distribution, cold storage facilities, freight rates, what effect the low grade apples

were having on these markets and to what extent the low grade fruit influenced the sale of a first-class article.

The information obtained was set down as soon as it was transmitted in order that the facts might be presented to the grower in the same form in which they were received. Following the completion of the survey, the facts were compiled and prepared in such a way as to be more convincing to the grower. The survey showed that of the total business in the South 32.5 per cent of the apples were packed in barrels. Of this amount certainly not more than 25 per cent was grown in Virginia and probably not more than 8 per cent of the total amount of apples handled in the South this year were Virginia barrelled stock. Dealers stated that five or ten years ago from 65 per cent to 75 per cent of the apples handled in the South were produced in Virginia. The past year it would not exceed 10 per cent.

Organizing the Growers

Following the investigation made by the Extension Division, a conference with several of the leading fruit growers was called. The purpose of this conference was to determine what the procedure should be in placing the facts before the growers, and to organize them in such a way that inspection rings could be formed and the pack inspected so that the package could carry with it a mark of distinction, possess merit, and serve as a guarantee of quality and dependability to the trade. This conference decided that a general meeting be held of representative fruit growers to formulate plans and learn what steps would be necessary in organizing inspection rings in the different counties, what standards would be adopted and how the rings would be financed, and to select representatives who would be willing to assume the initiative and act as leaders in their local community. A committee known as "The Trade Committee" was appointed which was to function by giving publicity to the proposed standardization of Virginia apples. The general meeting which was held a short time later was the beginning of the standardization and inspection work. At this meeting, local committees were formed and instructed to work out preliminary plans for their respective communities.

A series of meetings were held in different localities and organizations perfected. The growers were to furnish the supply of fruit and guarantee to pack it in such a manner that it could be offered to the distributors with a guarantee. Each package was to carry with it a stamp indicating that it had been inspected as packed. The growers were supplied with literature and with copies of the Virginia standards for grading, packing and inspecting of apples.

Each grower who agreed to accept inspection was required to sign a contract, either with his packing house corporation or with the fruit growers organization which was authorized to supervise the formation of the ring. This applied to all members packing through a community house and to individual growers outside of any such organization. A secretary was appointed for each ring and contracts

were turned over to him. Each member signing the contract was required to list his estimated crop in barrels according to varieties.

The secretary of the ring was authorized to pay the cost of inspection, advertising, instruction, etc. In many instances the cashier of the local bank acted in this capacity. The number of barrels estimated of each variety was summarized in order that the man in charge might have some idea as to the amount of money required for paying for this service, the amount to be based upon the number of barrels which would actually receive inspection.

This procedure was necessary before the banks would agree to advance any money. It was also necessary for the grower to give his note to the bank before it could advance any money. In most cases a blank note was given on the face of which a certain amount per barrel was stipulated. As a rule this cost was not to exceed six cents. In addition to this a charge of one cent was included to cover the cost of advertising.

At the conclusion of the harvest season, the number of barrels inspected for each grower or corporation was presented to the bank, whereupon a note was drawn to cover the actual cost of the service rendered.

Results

Twenty-three rings were organized in 13 counties with a sign-up of 451,497 barrels contracted for inspection. Of this amount 220,741 barrels were actually inspected as compared with 69,000 in 1923. The reduction of the number of barrels inspected as compared with the number contracted for was due to unfavorable weather conditions which produced a late infection of fungous diseases and prevented much of the fruit from passing inspection.

The cost of inspection for the different rings will vary, but the cost to the grower is on an average much less than the benefits received. The average cost for the state is approximately three cents per barrel.

The inspection service was handled through the State Division of Markets. Inspectors were appointed and trained by them and were under their direct supervision during the entire harvesting period. The extension specialists cooperated with the Division of Markets in conducting grading and packing schools and often rendered service to the inspectors while in the field. The extension workers were also called upon, in some instances, to render assistance in communities where differences occurred.

Work of the Trade Committee

Although this committee consisted of men having no connection with the State Department, the extension specialists were present in all of their meetings and assisted materially in the preparation and distribution of literature. Several letters to growers and dealers were prepared during the season and received a very wide distribution. The letters prepared for the trade were sent to about 8,000 dealers of good rating located in cities of 5,000 population or over in all the states east of the Mississippi River. The growers were kept informed

at all times as to the progress which was being made by the Trade Committee and on the other hand the trade was kept informed at all times as to the progress made by the growers. Just before the harvest season the dealers were furnished with a list of all growers who would pack under state inspection. This list contained the name of the grower, his address, the number of barrels he would have for sale, and the variety.

In addition to this, a full page ad was carried in five issues of the New York Packer. Thousands of cook books, posters and stickers were distributed, advertising Virginia apples and the fact that they were standardized.

Summary

In conclusion I would like to add that although we had some opposition from the buyers and criticisms on the part of some growers, the project as a whole was very satisfactory. From the results of a questionnaire which was sent out at the close of the harvest season there is every reason to believe that the standardization and inspection of Virginia apples is bound to increase. The majority of the growers were very emphatic in asserting that this is the best move that Virginia growers have ever undertaken and that it is the strongest piece of work which the Horticultural Extension Department has ever rendered.

The organization is far from being perfect, but we believe that with the experiences we have had this past season, together with the lessons which we will learn in the future, that we will be able to build a type of service which will be invaluable to the growers. Our specifications or grade requirements are sufficiently flexible to meet conditions, in fact certain minor modifications are receiving our serious consideration at this time. We believe as time goes on, the requirements will be made more rigid so that we may be better able to compete with the sections that are establishing standards of perfection.

An effort is being made and preliminary steps have already been taken to secure a sign-up of not less than 1,000,000 barrels to be contracted for inspection in 1925 and from present indications we have no doubt but that this can be accomplished. The inspection work has done more toward making the grower realize that the first and greatest step towards successful marketing is to have fruit so grown and so packed that it will withstand competition from any section.

Virginia Mountain Grown Seed Potato Demonstrations

By A. G. Smith, *Virginia Polytechnic Institute, Blacksburg, Va.*

THE demonstration work discussed in this paper was started in 1921, coincident with the beginning of vegetable extension in Virginia as a separate project. It deals with the most important truck crop of the State, and is intended to serve, not only the potato growers of Eastern Virginia, but farmers in the elevated sections of the state as well.

The potato seed project was outlined with two definite ideas in mind:

First, to stimulate interest in the use of high grade seed potatoes in Virginia; and, *second*, to create a supply of such seed within the state. To plant the early potato crop in Virginia, 2,500,000 bushels of seed are required of which more than 1,500,000 bushels, or 60 per cent of the whole, is purchased from out of state points.

Years ago the most progressive truckers of Eastern Virginia established the custom of visiting the fields in Maine and Canada from which their seed potatoes were purchased. This practice became necessary because of the inferior quality of much of the seed bought on the open market. The result of this practice is that different groups of truckers and individuals prefer seed potatoes from particular farms or localities from which they have purchased seed in past years.

In spite of the attention given to the source and quality of seed potatoes purchased, our truckers have suffered heavy losses from outbreaks of diseases which were known to be seed borne. The average trucker has failed to recognize some of these diseases and to distinguish between the loss resulting from the presence of these and that caused by unfavorable cultural and seasonal conditions. In addition to the trouble with diseases, Virginia potato growers have purchased large quantities of seed which were not of high yielding strains and as a result made yields too low for profitable production.

Accomac and Northampton Counties, constituting what is known as the Eastern Shore of Virginia, produce the greater part of the state's early potato crop and plant large quantities of northern grown seed.

The first phase of the seed potato project provided for a series of demonstration plots on the Eastern Shore, to be conducted in connection with meetings and county tours.

The second phase dealt with the production of seed potatoes in the elevated areas of Western Virginia. The farmers there, who are interested largely in beef cattle, are much in need of a cash crop. The high elevation of some of this land, together with the fact that it has never been used for potatoes, seems to render it ideal for the production of seed potatoes.

Some cooperative experiments between the Agronomy Department of the Virginia Agricultural Experiment Station and the Virginia Truck Experiment Station, had shown that seed potatoes could be grown at high altitudes in the mountains of the state which would prove satisfactory for Eastern Virginia plantings.

The work connected with the two phases of this project was carried on simultaneously. However, the amount of preliminary work required to establish it made it impossible to conduct systematic demonstrations before the spring of 1923.

The seed production work in the mountains was confined to the Cobbler and V. P. I. Green Mountain varieties. The latter is a strain of Green Mountain originating from hill selections made in 1909 by Professor T. B. Hutcheson at the Virginia Agricultural Experiment Station. The strain closely resembles the parent variety and so far as can be observed differs from it only in yielding ability and possibly shows some improvement in quality over Green Mountain. For 13 years this strain has been grown in the variety tests on the Experiment Station grounds and has averaged 19.56 bushels per acre or 11.9 per cent more than Green Mountain.

V. P. I. Green Mountain seed has been distributed to farmers in varying quantities by the Experiment Station. In every instance it gave such satisfactory results that the demand for it has steadily increased. The Experiment Station could produce only a limited quantity for distribution and most of the farmers found it so good that they either sold the potatoes for table stock or consumed them at home, instead of carrying over a surplus supply of seed.

In the fall of 1922, the Experiment Station arranged with the Extension Division to supervise the production and distribution of V. P. I. Green Mountain potatoes. The following spring seed was sent to farmers in eight different counties. Instructions for treating the seed, spraying, cultivating and roguing the crop were furnished and demonstrations given. However, the areas planted were too small from the grower's viewpoint to merit the careful attention required in the production of seed potatoes.

During the past season five acre fields were the smallest recommended for seed production. On this basis, the grower could provide the necessary equipment to produce the crop so as to conform to the requirements for certification.

Prince Edward Island and Maine seed was used for the initial plantings of Cobblers in the mountains. These were selected with the greatest care and planted at various altitudes in five counties. Potatoes had never been planted on the farms used, except in gardens.

The same was true of the Cobblers as of the V. P. I. Green Mountains. Those who made small plantings of Cobblers in 1922 failed to care for them properly. Larger plots were grown in 1923 and 1924, and these were sprayed and rogued with the greatest care. The altitude of these fields varied from 2100 to 4000 feet. All the potatoes matured before frost, the vines at the highest altitude being the last to die.

Fertilizers and Soils

The mountain fields were located chiefly on Hagerstown loam where an average application of 800 pounds of fertilizer was made per acre. This fertilizer carried five per cent ammonia, eight per cent phosphoric acid and five per cent potash. On one field of the Dakalb series only 600 pounds of the same fertilizer was used. In this case the V. P. I. Green Mountain was planted and made a yield above 300 bushels per acre on part of the field. The Cobblers in the mountain field have yielded from 200 to 340 bushels per acre. In most cases the yield was close to 300 bushels. No difference was noticed between the crop from northern grown seed and that from home seed of the same quality when planted together in the mountains.

Inspection and Certification

The high quality of the seed is maintained through a system of rigid inspections. This has been handled largely by the Extension Division in connection with field demonstrations. The certificates are issued by the State Crop Pest Commission.

Approved methods for insect and disease control are followed. Each field has been rogued two to four times. The grading has been done by hand and all off-type or injured tubers removed. Only one variety is grown on a given farm and only one recommended for use in any community.

Storage of Seed Potatoes

Interesting points developed during the course of these demonstrations bearing upon the storage of seed potatoes. Two car loads produced at an altitude of 2100 feet in the western part of the state were placed in cold storage early in September where they remained until March 1. When planted these potatoes were prefectly dormant and sound. The spring season was unusually cold and wet. The seed from one car, planted in Norfolk, Nansemond, and Princess Anne counties, failed to germinate at first and later gave a very irregular stand. The other car, planted on the Eastern Shore, met with somewhat better weather conditions, but did not germinate uniformly. It is interesting to note that the seed in both cars was subjected to a temperature of 30° F. for an indefinite period. It was later raised to 36°F. and held there until planted.

Twenty barrels from the car shipped to the Eastern Shore were held in cold storage until August 1 and were then allowed to sprout before being planted. In this instance the stand was almost perfect and the yield equal to that from the best seed planted from other sources.

As opposed to the methods outlined above, another lot of mountain grown Cobbler seed was shipped to the Eastern Shore early in the fall and held in a cellar under the north side of a barn where excellent natural ventilation was provided. This seed had begun to germinate when planted and came up before northern grown seed.

It was this lot which made the highest yield in the demonstration plots where it was referred to as Virginia Mountain—3000 feet.

During the present year most of the mountain seed is stored in ventilated houses.

Eastern Shore Demonstrations

In 1923, a series of demonstration plots was arranged on the Eastern Shore in which potato seed (of known origin) from different sources was planted. The plots were located on the edge of potato fields, where areas 100 feet long and as wide as necessary were planted by hand. One hundred seed pieces were dropped in each row. All were treated with corrosive sublimate. The fertilizer was uniform. A planting map was made for each plot and the rows marked at each end.

Row	Source of Seed
1	Prince Edward Island
2	Prince Edward Island
3	Virginia Second Crop
4	Prince Edward Island Home Grown
5	Prince Edward Island Home Grown
6	Virginia Second Crop
7	Virginia Mountain Grown (2100—V. P. I.)
8	Virginia Mountain Grown (2100—V. P. I.)
9	Virginia Second Crop
10	Virginia Mountain Grown (3000—Tazewell)
11	Virginia Mountain Grown (3000—Tazewell)
12	Virginia Second Crop
13	Virginia Mountain Grown (4000—Washington Co.)
14	Virginia Mountain Grown (4000—Washington Co.)
15	Virginia Second Crop
16	Maine Grown—Certified
17	Maine Grown—Certified
18	Virginia Second Crop
19	Maine Second Crop
20	Maine Second Crop
21	Virginia Second Crop
22	South Dakota
23	South Dakota

The outstanding feature of the 1923 plots was the appearance and yield of potatoes from mosaic seed. The yields made by the mosiac seed were approximately one-third of the average for all good seed in the plots. Some growers whose poor yields during the preceding year were due to mosiac did not realize until they saw the demonstrations where their trouble lay.

The 1924 plots were arranged like the 1923 plots, with the addition of Virginia Mountain Cobblers. Seed from three altitudes in the mountains, 2100, 3000, and 4000 feet, respectively, were shipped to growers on the Eastern Shore. The demonstrations in 1923 had been the subject of much discussion and many arguments among these growers. With the addition of the Virginia Mountain seed in 1924 the interest was greatly increased.

Our potato growers believe as others do that seed for the early crop must be immature when planted. They have shown beyond a doubt that their second crop, immature seed, will out-yield northern grown seed, but mature the crop a week or ten days later. They were convinced that the mature conditions of the Virginia Mountain seed would render it unfit for their purposes.

The arrangement of the 1924 plots is illustrated in the preceding diagram.

In five of the eight plots the Virginia Mountain seed, 3000 feet, was the first to break through the ground. The growers felt that some mistake had been made in labeling the rows. The planting maps were produced and their doubts on this point dispelled.

By the time they were in blossom the Virginia Mountain seed plants could be recognized by the peculiar shape of the tops. Very low and spreading, with broad leaflets, they presented in outline almost a semi-circle above the ground. They were like the tops from the Prince Edward Island seed, but were not so upright.

Careful records were kept of the demonstration and yields made by each lot of seed determined by weighing. The yields of the 1924 plots are summarized in the following table.

Source of Seed	Barrels per Acre—Average 8 plots
Virginia Mountain 3000 feet	100
Virginia Mountain 4000 feet	96
Virginia Mountain 2100 feet	90
Prince Edward Island, Canada	100
	Average 7 plots
South Dakota	94
Virginia Mountain 3000 feet	104
Virginia Mountain 4000 feet	99
Virginia Mountain 2100 feet	93
Prince Edward Island, Canada	104
	Average 6 plots
Maine, Certified	95
Virginia Second Crop	80
Virginia Mountain 3000 feet	106
Virginia Mountain 4000 feet	101
Prince Edward Island, Canada	104
Virginia Mountain 2100 feet	94
Virginia Second Crop (Maine)	79
	Average 4 plots
South Dakota	100
Maine, Certified	101
Virginia Mountain, 3000 feet	117
Virginia Mountain 4000 feet	111
Virginia Mountain 2100 feet	100
Virginia Second Crop	87
Virginia Second Crop (Maine)	81
Prince Edward Island, Canada	110

The high yields made by the Virginia Mountain seed were no doubt due to some extent to the freedom of this stock from disease.

One of the demonstration plots in Accomac County showed the following percentages of all disease when counts were made.

Maine certified	30
Prince Edward Island	7
Virginia Mountain, 3000	3

The yield for the same plot is:

Maine	232.0 pounds
Prince Edward Island	245.0 "
Virginia Mountain, 3000	265.5 "

In order to center the attention of the potato growers upon the demonstration plots, annual county tours have been conducted. Demonstration plots were visited and matters of interest pointed out by representatives of the Extension Division and the Experiment Stations. In 1923, a combination tour and institute proved fairly successful, the tour covering the first half of the day and the institute the second half. During the present year, better results were obtained through all-day tours with short talks at the lunch hour.

In conclusion, the project described in the foregoing paragraphs, presents methods for developing what may prove a new and valuable industry for Virginia mountain farmers in producing seed potatoes equal in quality and perhaps cheaper than those now being used in Eastern Virginia. Furthermore, the truckers could keep in closer touch with the production of the seed than they can possibly do when purchasing them from distant points.

An unlimited supply of such seed can be produced by our mountain farmers without much if any additional labor. They would stabilize their farming practice by adding this cash crop which would not conflict with their chief work—the production of beef cattle.

The Agricultural College serving as a connecting link between the two extreme sections of the state, is enabled through this project to serve the two in a direct and useful manner.

From the extension viewpoint the project embodies several unique features. It is new alike to our truckers and mountain farmers, and points to a common goal that would result in mutual benefits to the producers and purchasers of the seed. Results of experiments warrent its continuation. It opens the way for teaching valuable lessons through demonstrations. to those who are responsible for making Virginia the leading state in the production of early potatoes.

Copper Hydroxide as a Substitute for Bordeaux

By H. D. Hooker, Jr., *University of Missouri, Columbia, Mo.*

DURING the past two years the Department of Horticulture at the University of Missouri has been conducting spraying experiments with cupric hydroxide in a finely divided state. The material is obtained as a pale blue precipitate when a solution of

sodium hydroxide is added to a solution of copper sulphate in proper proportion. If an excess of sodium hydroxide is added, the color of the precipitate changes from light blue to dark blue and eventually to black. This black compound is cupric oxide. Cupric hydroxide is a gelatinous metal hydroxide that can be obtained in a colloidal solution by the removal of electrolytes. Cupric oxide is a gritty precipitate that has no tendency to form colloidal solutions.

In preparing colloidal copper hydroxide it is not only essential to avoid the formation of copper oxide, but to obtain the best results it has been found advisable to regulate the concentrations of the solutions of copper sulphate and sodium hydroxide, the temperature at which the reaction is carried out and the hydrogen-ion concentration of the resulting mixture. The precipitate of copper hydroxide is obtained in a more highly dispersed state at first when the reacting solutions are very dilute, when the temperature is kept as near the freezing point as possible and when just enough alkali is added to bring the pH value of the final solution to 4.5.

The mixture obtained by mixing copper sulphate and sodium hydroxide contains a precipitate of copper hydroxide and sodium sulphate in solution. To obtain the copper hydroxide in a colloidal condition it is only necessary to remove the sodium sulphate. The presence of insoluble impurities has apparently little effect on the dispersion of the copper hydroxide and so it is not necessary to use pure reagents. The ordinary grades of copper sulphate used in preparing Bordeaux mixture and commercial sodium hydroxide were found to be entirely satisfactory.

At first the copper hydroxide was allowed to settle by sedimentation and the soluble salts were removed by decanting the supernatant liquid. Although colloidal copper hydroxide was prepared by this procedure, it was so slow and so many washings were required that a quicker method was sought. The method finally used was the separation of the precipitate from the liquid in a centrifuge. This is much more rapid and effects a more thorough separation. It was later found to have another advantage, as the rapidity with which the copper hydroxide is washed free from the sodium sulphate after its precipitation is an important factor in obtaining a colloidal material. Practically all electrolytes were removed in a few washings. As soon as the copper hydroxide was freed from electrolytes it tended to go into solution from which it was not thrown down by ordinary centrifuging. In order to prepare a truly colloidal preparation, the last washings must be made in a super-centrifuge. For spraying tests, however, it was not considered necessary to obtain the maximum degree of dispersion, and the final washings in a super-centrifuge were omitted. Distilled water was used for washing the copper hydroxide, because the local supply of tap water was very hard and consequently not suitable for the complete removal of electrolytes. It is advisable that the water used for washing be as cold as possible. Hot water tends to change the copper hydroxide to the black copper oxide.

The copper hydroxide prepared for spraying tests was a highly

hydrated, gelatinous precipitate which formed a highly dispersed suspension when mixed with ordinary water in a spray tank. It is characterized by a positive electrical charge which gives it much the same sticking properties as lead arsenate. Colloids are thrown out of suspension by colloids with the opposite electrical charge. Hence muddy water, which is a suspension of a colloid with a negative charge, tends to destroy a suspension of copper hydroxide. The copper hydroxide suspension is, however, entirely compatible with lead arsenate that has a positive charge. When applied alone, it leaves no stain and so could be used as a late spray on cherries and grapes.

The detailed results of spraying experiments with the copper hydroxide suspension will be tabulated elsewhere. For the purposes of the present discussion they may be summarized as follows: Copper hydroxide has been found to be fungicidal against those diseases which can be controlled by Bordeaux mixture. Thus, for example, it will control apple blotch, apple scab and cherry leaf spot. Copper hydroxide has not proved effective against those diseases, such as the cedar rust of apples and carnation rust, which are not controlled by Bordeaux mixture. Furthermore, copper hydroxide produces burning on those fruits that are susceptible to Bordeaux burning and does not burn those varieties which are relatively resistant to Bordeaux burning. For example, copper hydroxide in concentrations as weak as one part in 25,000 produced burning on Jonathan apples, when applied as a calyx spray this past spring; while Oldenburg suffered no injury from concentrations five times as great. It may be concluded, therefore, that qualitatively the fungicidal and burning properties of Bordeaux and copper hydroxide are identical, a fact that may be taken as further evidence, if any be needed, that the fungicidal properties of Bordeaux are due solely to its content of copper hydroxide.

Quantitively, however, there is a vast difference between Bordeaux mixture and the copper hydroxide suspension On the basis of the copper content, the copper hydroxide is approximately 15 times as effective as the Bordeaux, for a suspension containing one part of copper hydroxide in 5,000 of water has given control of apple scab, apple blotch and cherry leaf spot equivalent to that of 3-4-50 Bordeaux. The only factor to which this quantitative difference in the fungicidal powers of the two copper sprays can be attributed is the physical state of the copper hydroxide. In Bordeaux the copper hydroxide is present as a flocculent precipitate mixed with calcium sulphate and an excess of lime. In the copper hydroxide spray it is present as a highly hydrated, highly dispersed suspension that distributed itself evenly and uniformly over the surface of the plant. The effect of dispersion on both the fungicidal and burning properties of copper has been observed not only in the comparison of Bordeaux and copper hydroxide, but also as between copper hydroxide preparations of varying degrees of dispersion.

This effect of dispersion on the fungicidal strength of copper sprays is very suggestive. It is well known that the degree of dispersion is one of the chief factors affecting the action of catalytic agents.

Furthermore, copper is an oxidizing catalyst that has been found to be effective in oxidizing exceptionally inert compounds. Cupric oxide is one of the ingredients of hopcalite, the material prepared by the Chemical Warfare Service for use in gas masks to oxidize carbon monoxide to carbon dioxide. It may be mentioned, incidentally, that colloidal copper hydroxide has also been used commercially to effect the oxidation of carbon monoxide. The action of copper in catalysing biological oxidations has also been noted. Valdiguie (Compt. rend. soc. biol. 88: 1091–1092, 1923) observed that copper salts in the presence of air have much the same action as oxidizing enzymes.

It may be concluded, therefore, that the fungicidal and burning action of copper sprays depend upon the catalytic action of copper in effecting oxidation. This confirms the opinion of Dubois (Compt. rend. 176: 1498–1500, 1923) that copper and its salts appear to destroy molds by an action comparable to that of oxidases and peroxidases and not by any direct toxic action.

The Effect of Some Spraying Materials Upon the Rest Period of Fruit Trees

By W. C. Dutton, *Agricultural College, East Lansing, Mich.*

OCCASIONAL reference is made in the literature to stimulating and retarding effects that various spraying materials may have on the growth of fruit trees. No effort will be made to give a complete review of the literature, but a few statements will show the general trend of work along this line. A number of years ago some workers in South Africa reported that, in general, oil sprays would advance the blooming period while sprays containing lime would delay it. In this country fall applications of sprays of lime-sulphur, lime-sulphur and salt, and lime-sulphur and soda, have caused serious injury to fruit and leaf buds on several fruits and retarded the development of the trees in the following spring. Oil sprays have both stimulated and retarded blooming of some of the common deciduous fruits. In California, under certain conditions and with certain fruits, it is reported that late fall or early winter applications of heavy miscible oils are used to advance the blooming period and to stimulate leaf growth. If such application is delayed later than a certain point, or if there is a lack of moisture or plant food, the results will not be positive. No mention has been made, so far as the writer is aware, of any effect that these materials might have on the rest period of the trees and it is possible that the rest period was not concerned in any of the cases reported.

In 1923, an item appeared in a trade paper to the effect that peach trees in Georgia which had been fall sprayed with a certain material suffered greater winter injury than those not so sprayed. It occurred

to a member of the Horticulture Department that this might be due to an early breaking of the rest period of the trees so that they started into growth during a warm period and were injured by succeeding periods of cold weather. To determine what effect spraying materials might have on the rest period of fruit trees some work was begun in the fall of 1923.

The materials used were as follows:

Lime-sulphur, 6¼ gallons in 50.
Soluble sulfur (a sodium compound) 12½ pounds in 50 gallons.
Scalecide, 1 to 15.
Sunoco spray oil, 1 to 15.

Another material, nitrate of soda, which is known to be effective in breaking the rest period of plants was also used. These materials were all applied in late November during a period of mild weather. The fruits used were Kalamazoo and Fitzgerald peach and Clapp pear. All varieties were not sprayed with all materials.

Shoots were cut from the trees 12 days after spraying and set in water in a greenhouse. The Kalamazoo peach and Clapp pear received the same treatments and the results may be stated in a general way as follows. Twenty-one days after cutting the unsprayed shoots and those sprayed with lime-sulphur were inactive. Soluble sulfur and sodium nitrate sprayed shoots were very active. Fruit buds were developing rapidly on the peach and leaf buds on the pear (there were practically no fruit buds present on the pear). Scalecide sprayed shoots of Kalamazoo were active, both leaf and fruit buds growing actively. On pear the buds appeared dormant, but the reason they did not grow was that they were dead. No growth developed at any time on scalecide sprayed pears on cut shoots in the greenhouse. The killing was much more severe on such shoots than those remaining on the trees.

Thirty-three days after cutting, unsprayed and lime-sulphur sprayed shoots were still inactive. Shoots sprayed with soluble sulfur and sodium nitrate had continued growth although all buds did not develop evenly. Many blossoms were opening on peach shoots sprayed with soluble sulfur. Scalecide sprayed peach shoots did not continue development, but showed considerable injury.

Shoots from trees of Fitzgerald peach developed more or less uniformly regardless of treatment.

Another lot of shoots was cut on January 3 and treated in the same manner as the first lot. All peach shoots or buds in this lot which had not been injured by the spray developed in a very uniform way, regardless of the treatment, indicating that the rest period had probably been broken by natural agencies before the shoots were cut. With the pear, soluble sulfur and sodium nitrate sprayed shoots began growth in 16 days while the checks and lime-sulphur sprayed shoots were inactive at that time. There was no evidence of any acceleration or retardation of bloom or leaf growth in the following spring.

The results obtained from this work are not entirely conclusive, but indicated very strongly that certain spraying materials may be effective, under some conditions, in breaking the rest period of peaches and pears.

Chemical Changes During the Growth and Ripening of Pea Seeds*

By V. R. Boswell, *University of Maryland, College Park, Md.*

Introduction

IT IS well known that the consumer prefers the small sifted peas instead of the larger and less expensive grades. When purchasing green peas, one discriminates against those which have the appearance of being near maturity, and one is willing to pay a premium for a product which will yield tender, immature peas upon shelling. Why is there such a discrimination in favor of the young and immature product? What chemical constituents are responsible for this high quality, or for a poor quality? What occurs during the ripening and development of the seeds to account for the great differences in quality? The answers to these questions were sought, in part, by determining the percentage of certain of the chemical constituents in the developing seeds, at frequent intervals between blossoming and maturity. It was also considered of interest, from the physiological standpoint, to know something of the processes going on within the young seed as it develops and ripens. Are the chemical changes during the development of peas typical of those known to exist in the seeds of some other of our crop plants?

Sampling

Care was taken to insure that all the peas sampled on a given date were as near the same age as possible, in order to lower the variation in composition accompanying differences in age. Several hundred blossoms, *fully* opened, were tagged on May 20, 1922; then peas taken for analysis included only those developed from blossoms which had been tagged. Thus there was very little variation in the age of different individuals composing a sample. This method of securing peas of the same age for a given sample, was followed also in the 1924 work. Due to seasonal variation and to late planting, however, the blossoms were not tagged in 1924 until June 5.

*The writer wishes to acknowledge that this work was originated by Dr. H. A. Jones, now located at the University of California and formerly connected with the University of Maryland. Due to Dr. Jones' departure for California soon after starting this work in 1922, progress on the problem was stopped for a time. The press of other activities prevented the writer from taking up the work until the past season, when analyses of the 1922 samples were made and also another series of samples was taken and analyzed.

In 1922, samples were taken 10, 12, 14, 17, 20, 22, 24 and 26 days after full bloom; in 1924 they were taken 14, 16, 19 and 22 days after full bloom. The peas from 10 to 30 pods, depending upon the size of the peas, constituted a sample. Samples were taken in duplicate or in triplicate, and the results of the analyses, with few exceptions, are expressed as averages of duplicate samples.

Methods of Preserving Samples

Incidently, some very interesting and important facts regarding the method of killing and preserving plant material have been found in this work. At this point, only a general statement regarding the methods of preserving the material will be made, and a discussion of the results will be given later.

In 1922, the majority of the samples were preserved in the following manner: Eighteen to 20 grams of peas were removed from the pods immediately after harvesting, were weighed, and then dropped into such a quantity of cold 85 per cent alcohol that the final concentration would be about 75 per cent. Two-tenths gram of calcium carbonate was added to neutralize any acid present. There were four exceptions to this procedure in which, after weighing, the peas were dropped into boiling 85 per cent alcohol on the water bath, immediately removed, allowed to cool, and then stored along with the other samples.

All samples taken in 1924 were killed by dropping the weighed peas into a quantity of boiling alcohol sufficient to give a final concentration of approximately 75 per cent, and boiled under a reflux condenser for three to five minutes to insure an immediate and complete inactivation of all enzymes. This procedure proved to be the most satisfactory, as will be shown later.

Methods of Analysis

Grinding and Extraction. The alcohol in which the peas were preserved was decanted off into a 500 cc. volumetric flask, and the peas were transferred to a mortar. The peas were ground, with a little alcohol, to a uniformly fine, creamy consistency, transferred to a 250 cc. wide-mouthed Erlenmeyer flask and then about 75 cc. of 75 per cent alcohol were added. The flask was placed in a water bath under a reflux condenser, brought to a boil as quickly as possible, and boiled for 15 minutes. The mixture was then filtered rapidly on a Buchner funnel, washed with a little 75 per cent alcohol, and returned to the Erlenmeyer flask. The process was twice repeated, all filtrates and washings being combined with the original preserving alcohol in the volumetric flask. This was called extract one. This procedure was followed in order to extract as much of the soluble nitrogenous substances as possible before subjecting the tissue to drying. Drying is known to render much of the soluble nitrogen, insoluble.

After the third extraction and filtering, the residue was transferred quantitatively to a small dish, dried at 55°C. and ground to

pass through a 100-mesh sieve. The ground residue was divided into suitable aliquots to be analyzed for starch, hydrolyzable polysaccharides and insoluble nitrogen, respectively. The aliquots were placed in Whatman extraction shells and extracted for two hours with alcohol in Soxhlet extraction tubes. The alcoholic extracts from all three aliquots of residue were combined and called extract two.

Extract two was then added to an aliquot of extract one corresponding to the proportion of the total residue which was subjected to extraction in the Soxhlet tubes. This final combined extract was called extract three; aliquots were taken from this extract for the determination of sugars, total soluble nitrogen and the various soluble nitrogen fractions to be discussed later.

The extracted residues were dried at 80°C. and weighed for the estimation of dry matter. The dry matter in the alcoholic extract was determined by weighing the residue remaining after evaporating an aliquot of the extract to dryness.

Starch, Sugars and Polysaccharides. The methods used in the determination of starch, sugars and acid hydrolyzable polysaccharides are essentially the same as those described in Maryland Experiment Station Bulletin No. 258.

Insoluble Nitrogen. An aliquot of the extracted residue of the pea tissue was subjected to the Gunning modification of the Kjeldahl method of determining nitrogen.

Alcohol-Soluble Nitrogen. A 50 cc. aliquot of extract three was transferred to a Kjeldahl flask, the alcohol driven off on the water bath, and the nitrogen determined by the Gunning-Kjeldahl method.

Distribution of Alcohol-Soluble Nitrogen. The methods involved in the determination of (1) Amide plus ammonia nitrogen, (2) Basic nitrogen, (3) Mono-amino-acid nitrogen, and (4)Humin nitrogen are the same as those used by Jodidi (4) in his studies of the nitrogen distribution of spinach.

Presentation of Data

Tables I and II show the results of the analytical work outlined above, together with a description of the material analyzed, with respect to the age and the method of killing the tissue.

The two seasons' analytical results are not to be directly compared because of a difference in variety, and a difference in the method of preserving the samples. The Alaska was used in 1922 and Nott's Excelsior in 1924. However, with the exception of the relation of the reducing substances to sucrose, the changes in percentage of a given constituent give curves of the same general trend when expressed graphically.

During the growth of the seed there is a rapid increase in percentage of dry matter. Total sugars decrease very rapidly, there being an appreciable change from day to day. Accompanying this decrease in sugar content, there is a very rapid rise in hydrolyzable polysaccharides in the 1924 samples, and a less rapid rise in starch

content. The unexpected behavior of total polysaccharides in the 1922 samples is difficult to explain, unless it represents a condensation of the hydrolyzable materials to a complex form of polysaccharide which is not hydrolyzed by 2.5 per cent hydrochloric acid. It can hardly be accounted for by a hydrolysis of the polysaccharides to sugar because there is no corresponding increase in sugar content. The decrease in sugar content runs quite true to the typical reversible reaction curve, and a hydrolysis of a large amount of polysaccharide material would probably be evident in a change in direction of the sugar curve.

Two outstanding differences were found between the 1922 series and the 1924 series of samples. The first was the difference in ratio of reducing sugars to sucrose. The total sugar curves are similar in both series, even though they are some distance apart. It will be noted that none of the 1924 samples, which were killed by boiling in alcohol, showed more than a mere trace of reducing substances. While in the 1922 material which was, for the most part, preserved in cold alcohol, there was a very high reducing sugar content. As evidence that this is not a varietal difference, but that it is due to the method of handling the tissue, observe the reducing and total sugar content for pairs of samples of the same age and of the same variety, but killed by different methods. The difference in the percentage of reducing sugars in the hot and cold preserved samples of the ages of 20, 22, 24, and 26 days, indicates clearly that boiling alcohol has prevented the accumulation of reducing sugars. These sugars are normally present in very small amounts and have accumulated in certain samples during storage, at the expense of sucrose. There also seems to be a slight loss of total sugars in the cold preserved samples, but the data are too meagre to prove this point conclusively.

The second notable difference in the two sets of samples was that of starch and total polysaccharide content, there being an appreciable difference of both constituents. The Alaska contained much the more starch, and this percentage composed a very markedly greater proportion of the total hydrolyzable polysaccharides than was found in Nott's Excelsior.

Although the proportion of different sugars was markedly affected by the mode of preserving the samples, the nitrogenous constituents were not influenced to an appreciable degree. The two years' results upon nitrogenous constituents are in fairly close agreement. The maximum soluble nitrogen content is found in the youngest peas, and this rapidly decreases with age. Amide, amino, and humin nitrogen also decrease rapidly from the first, while the basic nitrogen rises to a maximum at an age of 14 to 16 days and then follows the trend of the other nitrogenous constituents. Total soluble nitrogen and all of the four above-mentioned components reach a minimum at maturity. The changes in insoluble nitrogen content are just the opposite—it is at a minimum in the youngest peas and reaches a maximum at maturity. Since both the heat and the alcohol in the extraction process precipitate proteins, we may use this insoluble

TABLE I.

Changes in Chemical Composition of Garden Peas

Year	Age in Days	Method of Killing	Dry Matter	Reducing Sugars	Sucrose	Total Sugars	Starch	Total Polysac- charides	Insoluble Nitrogen	Soluble Nitrogen	Total Nitrogen
1924	14	Dropped in hot alcohol; boiled	17.48	Trace	35.17	35.17	—	32.82	1.83	2.47	4.30
	16		20.36	"	33.72	33.72	8.75	39.67	2.35	1.56	3.92
	19		24.97	"	20.02	20.02	16.13	67.35	3.20	0.78	3.98
	22		30.35	"	9.60	9.60	21.35	82.16	3.32	0.57	3.89
1922	10	Dropped in cold alcohol; not boiled	17.63	26.83	8.11	33.99	—	41.36	1.53	2.90	4.43
	12		18.66	24.03	5.66	29.21	—	46.74	1.61	2.32	3.93
	14		19.75	16.21	5.30	21.51	20.99	64.77	1.83	1.97	3.80
	17		25.73	9.01	1.82	10.85	31.49	44.11	2.58	0.95	3.55
	20		35.04	4.01	1.72	5.73	36.27	51.17	2.63	0.45	3.15
	20	Hot alcohol	34.53	1.02	5.45	6.47	36.16	51.11	2.75	0.58	3.33
	22		40.71	Trace	5.46	5.46	34.36	51.16	2.93	0.43	3.36
	22	Cold Alcohol	43.31	3.71	1.05	4.76	36.63	51.10	2.92	0.45	3.36
	24	Hot Alcohol	54.86	1.01	4.19	5.24	33.22	47.78	3.17	0.35	3.52
	24	Cold Alcohol	51.87	3.33	0.97	4.30	35.13	50.27	3.00	0.43	3.53
	26		55.72	3.16	1.29	4.45	37.35	48.15	3.12	0.47	3.60
	26	Hot Alcohol	59.20	1.81	3.42	5.23	37.14	47.46	3.00	0.46	3.46

On dry weight basis.

TABLE II.

Changes in Nitrogen Distribution of Garden Peas During Development and Ripening.
(Expressed in terms of per cent of total nitrogen present)

Year and Variety	Age in Days	Total Nitrogen*	Insoluble Nitrogen	Soluble Nitrogen	Amide Nitrogen	Basic Nitrogen	Amino Nitrogen	Humin Nitrogen
1924 Nott's Excelsior	14	4.30	42.54	57.44	8.640	6.710	13.580	5.020
	16	3.92	60.13	39.86	4.565	10.085	8.370	3.725
	19	3.98	80.40	19.59	2.190	3.565	3.505	1.730
	22	3.89	85.34	14.66	1.640	3.470	1.900	Trace
1922 Alaska	10	4.43	34.49	65.51	12.710	5.940	14.740	—
	12	3.93	40.97	59.02	9.540	7.135	14.070	9.560
	14	3.80	49.30	51.69	8.560	9.460	9.625	8.840
	17	3.55	73.19	26.80	3.340	5.770	4.740	4.740
	20	3.24	84.56	15.43	1.253(?)	4.370	3.023	3.106
	22	3.36	86.91	13.09	2.020	3.230	1.235	2.096
	24	3.52	88.51	11.49	1.366	2.240	1.030	1.506
	26	3.51	86.77	13.23	1.056	2.340	1.030	1.503

*Total nitrogen in per cent of dry weight.

nitrogen estimation as a rough index to the protein nitrogen of the seeds.

Method of Preserving Samples

In regard to the method of preserving samples for analysis, it appears that besides the addition of alcohol, a boiling temperature is necessary to quickly and completely inactivate the enzymes. Preserving without heating may result in an inversion of sucrose, as occurred in this work, or even other hydrolyses may occur in the stored sample. This would obviously yield analytical results different than would have been secured if fresh tissue had been analyzed. Some workers may not be aware of the importance of this point, so a word of caution should not be amiss. Immersion of the tissue in strong alcohol may not be sufficient to stop all enzyme action immediately, but boiling for three to five minutes will secure the desired results.

Varietal Differences in Quality

What is the relation of the chemical changes during the ripening of peas, to the observed differences in quality? First, with respect to varietal differences, Alaska is known as a pea of but medium to poor quality, while Nott's Excelsior is considered of good quality. A comparison of the total sugar content of the Alaska and the Nott's Excelsior shows the former to be much less rich in sugar. It also has a much lower percentage of hydrolyzable polysaccharides, suggesting a higher percentage of insoluble, non-hydrolyzable substances of a refractory character which tend to lower quality. The starch content, however, is actually higher in the Alaska variety. When the polysaccharides other than starch were precipitated from aqueous solution by alcohol, during the process of starch determination, it was plainly evident that the Nott's Excelsior contained much greater quantities of these substances than did the Alaska. The great difference in amount of these soluble materials in the two varieties would seem to be an additional point in explanation of the difference in quality of the varieties in question. Other investigators (1) (2) have shown that the changes in sugar content, and the changes in the ratio of sugar to starch, are very largely responsible for changes in the quality of certain vegetable products. The same seems to be true in the case of the garden pea.

Changes in Quality of a Single Variety

In regard to the differences in quality of a single variety, late harvested peas have a distinctly lower sugar content and a higher starch and total polysaccharide content than those harvested 10 to 14 days after blossoming. The rapidity with which the sugar content falls and the less palatable substances (starch and other polysaccharides) accumulate, suggest a reason for the marked deterioration in quality of peas which are not harvested as soon as the seeds fill the pods well. In both varieties studied, the seeds had just filled

the pods well and were large enough for use 14 days after blossoming. This period of time will vary, of course, with the variety and with environmental conditions. If the peas are allowed to remain on the vines even a very few days after the pods are well filled, there is a marked loss of sugar, an accumulation of starch and a consequent lowering of quality.

The drop in the percentage of the simpler forms of nitrogen is evidently the result of the synthesis of these materials into complex and insoluble substances, as is suggested by the corresponding rise in percentage of insoluble nitrogen. Zaleski (6) used the garden pea in studying protein synthesis in plants. He noted a marked decrease in amino, basic and other soluble nitrogenous compounds after a period of five days, and an accompanying rise in protein nitrogen. Eckerson (3) found a similar set of changes in amino-acid and asparagine content accompanying the dehydration of the wheat kernel in the normal ripening process, and also in the artificial drying of immature seeds.

Since the completion of the work reported in this paper, a very interesting article by Albert L. Whiting (5) has appeared, in which he emphasizes the improvement of quality and yield of Alaska peas as the result of inoculation. It is shown that the inoculated plots bore a larger percentage of smaller sized peas than did the non-inoculated plots and the writer states that cutting at the proper time is advantageous in that it results in a better distribution of pea sizes. Figures are presented giving the "protein" content of different grades of peas from the inoculated and the non-inoculated plots. These figures were evidently obtained by multiplying the total nitrogen content by a factor, with the result that they are too high for protein. Much of the nitrogen of immature pea seeds is in the form of amides, basic substances and amino acids. Whiting explains that in delaying the harvest of peas for canning, there is a great loss in quality in an attempt to get an increased yield. The larger peas thus secured certainly are older and more nearly mature. He states that these larger peas are lower in protein content than the smaller and higher quality peas. The results obtained here at the Maryland Station show that the larger and more mature peas do have a lower total nitrogen content, but if we consider the insoluble nitrogen as an index to protein content instead of the total nitrogen, it will be evident that the larger and more mature peas have decidedly the higher protein content. This view is also in agreement with Zaleski's results.

Whiting states that the plants of the uninoculated plots were of relatively poor color and poor vigor, and that they "had reached an advanced stage of maturity many days before cutting;" whereas, the inoculated plots were of excellent color, vigorous, and were not so nearly mature. He found that the peas from the inoculated plots were higher in nitrogen than those from the uninoculated plots, and that they were of higher quality. Considering the difference in stage of maturity of the two different plots in the light of results brought out in this present paper, Whiting found just the differences in nitrogen content that we would expect.

The analyses reported in the present paper show rapid changes in chemical composition of peas during development and maturity, and it is known that peas deteriorate rapidly in quality as they approach maturity. So any treatment which keeps the plants in a vigorously growing condition, retarding the process of maturity, would be expected to check the rate of deterioration of quality to a greater or less extent. Inoculation, as reported by Whiting, has without question afforded an increased nitrogen supply for the plants, kept them more vigorously vegetative, and promoted good development so that a desirable size of peas was obtained while they were yet in a relatively immature condition. The writer does not imply that the entire difference in nitrogen content between inoculated and non-inoculated plants is due entirely to differences accompanying varying stages of maturity, but it seems that they can be accounted for very largely by those conditions. Thus, may not the influence of increased nitrogen supply through inoculation, be largely a matter of increased growth accompanied by delayed maturity?

The changes in quality then, brought about as a result of inoculation, seem to be due principally to the relatively great difference in chemical composition as a result of changing the rate of maturing of the peas. In the less mature state they have a much higher sugar content, a lower starch and hydrolyzable polysaccharide content, a lower insoluble nitrogen content and a higher total nitrogen content. It is not possible to say just to what extent each of these constituents influences quality, but it is probable that the sugars and starch play the greater part.

Summary

The growth and ripening processes in pea seeds are characterized by: (1) A rapid decrease of sucrose, total soluable nitrogen, amides, basic nitrogenous substances, amino acids and materials which form humin compounds upon hydrolysis. (2) An increase in starch, hydrolyzable polysaccharides and insoluble nitrogen. (3) A less rapid decrease in total nitrogen.

Low sugar content and high starch content are characteristic of peas of poor quality, either as a varietal characteristic or because of a too advanced stage of maturity before harvesting. The converse is also true.

Peas should be harvested promptly upon the attainment of marketable size in order to avoid great loss of sugar content and consequently, of quality.

Plant tissue to be preserved in alcohol for analysis should be placed in hot alcohol and brought to a boil as quickly as possible. Boiling for three to five minutes will quickly and effectively arrest enzyme action.

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The Relation of Chemical Composition to the Regeneration of Roots and Tops on Tomato Cuttings*

By A. L. SCHRADER, *University of Maryland, College Park, Md.*

STUDIES were made during 1920 and 1921 to determine, if possible, the relation between the chemical composition and the development of roots and tops on tomato cuttings. The tomato was selected to work upon because the cuttings were easy to propagate and also the work of Kraus and Kraybill (4) showed that wide variations in chemical composition could be obtained with the tomato plant with consequent variations in external response.

MATERIAL USED

Tomato plants of the John Baer variety were grown in flats filled with loam soil. When the plants had grown to the height of approximately two inches, a uniform lot of 200 plants were pricked off into two and one-half inch pots filled with garden loam. The plants were kept under good growing conditions until they reached eight or nine inches in height.

With the purpose of obtaining plants with a high carbohydrate and relatively low nitrogen content, 100 of these plants were grown in sand cultures in the following manner:

Six inch flower pots previously washed with hot water to remove any possible nitrogen, were used with a thin layer of cotton batting placed in the bottom of the pot to prevent the sand from washing through the drainage hole. The pots were then filled about one-third full of white quartz sand of the round grained type, and water was added in sufficient amount to have the water level about one half inch above the level of the sand. This water provided an easy means for spreading the roots of the plant in transplanting, and also prevented the occurrence of dry places or air holes around the roots. The roots of the plants were carefully washed and brushed free of organic matter before placing in the sand. Each pot was placed in

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a 10 inch saucer which had been previously painted with a waterproofing paint, the saucer acting as a reservoir to keep a constant water supply to all the plants. The pots were watered with tap water and also supplied at intervals with a nutrient solution lacking nitrogen as follows:

A. Magnesium sulphate, ... 2 per cent,
Diabasic potassium phosphate, ... 2 per cent,

B. Calcium sulphate, ... 4 per cent.

Equal parts of A and B were each diluted with seven parts of water, mixed and applied directly to the sand cultures. Thus the above set of plants were grown with practically no nitrogen supplied to the medium. During a six day period following transplanting microchemical tests on sample plants of this lot show very rapid accumulation of starch and transformation of nitrates to some other form of nitrogen in the plant. Six days reduced the nitrates to a trace, and starch was at a high point.

In order to obtain plants of a chemical constitution opposite to the above, that is, low in carbohydrates and relatively high in nitrogen, the remaining 100 plants were transplanted to large butter tubs filled with rich, sandy loam, made up with one part sand, one part leaf mold and two parts of silty loam. Five plants were placed in each tub.

As a result of the above treatment, two sets of plants were secured after a period of about seven weeks which showed wide differences in external appearances and chemical constitution. (Plate V.) The plants in the sand cultures were only 12 to 13 inches tall; basal leaves had fallen and showed a gradation from a yellow color in the lower leaves to a green color in the tip leaves. The stems were stiff

TABLE I

Analyses of Material Calculated to a Dry Weight Basis (March, 1921)

Material	Per cent Dry Matter	Per cent Reducing Sugars	Per cent Dextrins	Per cent Hemicellulose	Per cent Starch	Per cent Total Nitrogen	Per cent Nitrates
Non-vegetative Plant in Sand Culture....	12.23	3.65	4.61	20.11	14.08	0.93	.0018
Vegetative Plants in Rich Loam....	7.02	2.75	1.39	5.82	1.00	1.65	1.53

and woody and had a purplish color. Chemical analyses of the stems of these plants, using five plants for a sample, gave the results shown in Table I. This table shows that these non-vegetative plants were high in all carbohydrates, relatively low in total nitrogen and only a trace of nitrates. Microchemical tests for starch, reducing sugars, dextrins, lignin, and nitrates, were confirmed by the results of the quantitative analyses.

The plants grown in the rich loam were markedly different than the plants of the sand cultures. These plants had grown to a height

of 34 to 36 inches and possessed thick, succulent stems and large green leaves. The chemical analyses of these stems, in contrast to those of the sand cultures, were low in carbohydrates and relatively high in nitrogen, especially nitrates as shown in Table I.

These two sets of plants furnished material of widely varying composition which was used in the form of cuttings for the study of the regeneration of roots and tops.

Chemical Methods

Sampling: Duplicate samples were taken using five plants per sample. The stems of the plants were cut off at the base and the leaves were immediately removed. The stems were then cut up into three inch pieces and weighed, after which the stems were further cut up into small pieces about one-half inch in length and dried at 95° C. The samples when dry were weighed for dry weight and then ground to the fineness of flour.

Reducing Sugars: The Defren-O'Sullivan method was used to determine the reducing substances. The sugars were extracted by boiling in 90 per cent alcohol for 30 minutes, filtering and washing the residue with hot alcohol. The alcoholic extract was evaporated in vacuo at 50° C. then taken up with a little water and re-evaporated to remove all the alcohol.

Dextrins: The residues from the sugar extraction were extracted by boiling with 100 cc. of 10 per cent alcohol for 30 minutes and then washed with an equal volume of 10 per cent alcohol. The filtrate was evaporated in vacuo and hydrolyzed for an hour and a half with hydrochloric acid (10 cc. of concentrated acid to 100 cc. of extract). The solution was cooled, neutralized with sodium hydroxide and made up to volume. The reducing power was determined by the Defren-O'sullivan method.

Starch: Starch was determined according to the Official Methods of Analysis, U. S. Department of Agriculture Bulletin No. 107, which provides for diastatic digestion with taka diastase.

Hemicellulose: The residue from the starch digestion, after washing with alcohol, was hydrolyzed with two and one-half per cent sulphuric acid (by volume) for one and one half hours, neutralized and the reducing power determined by the Defren-O'Sullivan method.

Nitrates: A method outlined by Strowd (6). A 10 gram green sample was analyzed.

Total Nitrogen: A 10 gram green sample was analyzed according to the Kjeldahl method modified to include nitrates.

Microchemical Methods

All tests were made in triplicate on uniform cross-sections of fresh material. Reducing sugars, dextrins, starch, lignin, proteins and nitrates were determined in a roughly quantitative manner on a scale of 10. The methods used were those described by Eckerson (5). Picric acid test gave the best measure of the protein content.

Cuttings from Non-Vegetative Material with High Carbohydrate and low Nitrogen Content

Since Microchemical tests showed a gradient from high content of starch in the base to a relatively low content of starch in the tip of the non-vegetative plants, cuttings were taken from the tip, middle, and basal regions of the plant after removing leaves. Each cutting was three inches long and was planted at a depth of one and one-half inches in white quartz sand contained in 10 inch pots. The pots were placed in ten inch saucers which were kept filled with tap water, but no nutrients were supplied. All cuttings were then kept under ordinary greenhouse conditions.

At the end of four days when two cuttings were taken from each lot for microchemical tests, it was found that the basal cuttings had already regenerated short roots about an eighth of an inch in length whereas the middle and tip cuttings had regenerated no roots. None of the cuttings had regenerated shoots.

After six days, the basal cuttings had regenerated several small roots, but no shoot growth; the middle cuttings had produced neither roots nor shoots; and the tip cuttings had small shoots about one-eighth of an inch long, but had no roots.

After a period of 10 days, the basal cuttings had small shoots, the middle cuttings possessed a few small roots and a small shoot, and the tip cuttings had also regenerated a few roots.

Six representative cuttings taken from each lot after 23 days, showed a development of roots which was greatest in the basal cuttings and least in the tip cuttings. A very small shoot was present on all the cuttings. (Plate VI).

Microchemical tests at the internodal region of the cuttings made at frequent intervals during the above experiment show some decrease in starch content of the cuttings. This decrease in starch content was very marked in the case of the tip cuttings which were relatively low in starch at the beginning of the experiment.

The experiments with the above material indicates that there is an apparent relation between the carbohydrate content and the root regeneration on tomato cuttings. The development of roots was in direct relation to the gradient of starch content in the tomato plant from which the cuttings were taken. (Plate VI). Roots appeared first on the cuttings which had the highest starch content, that is, the basal cuttings, whereas shoots appeared first on the tip cuttings.

The amount of root growth upon the cuttings appears to be in relation to the size of the cutting. The cuttings had an average weight as follows: Tip cuttings 0.63 grams, middle cuttings 1.19 grams, base cuttings 1.87 grams.

Cuttings-From Vegetative Material With Low Carbohydrate and Relatively High Nitrogen Content

These cuttings were made and placed in sand as in the previously outlined experiment. Cuttings were selected at intervals to note root and shoot growth and to make microchemical tests.

PLATE V. The plants at left are typical of the non-vegetative material used in these experiments. The one plant at the right is typical of the vegetative material. The small pot at right was used for photographic convenience.

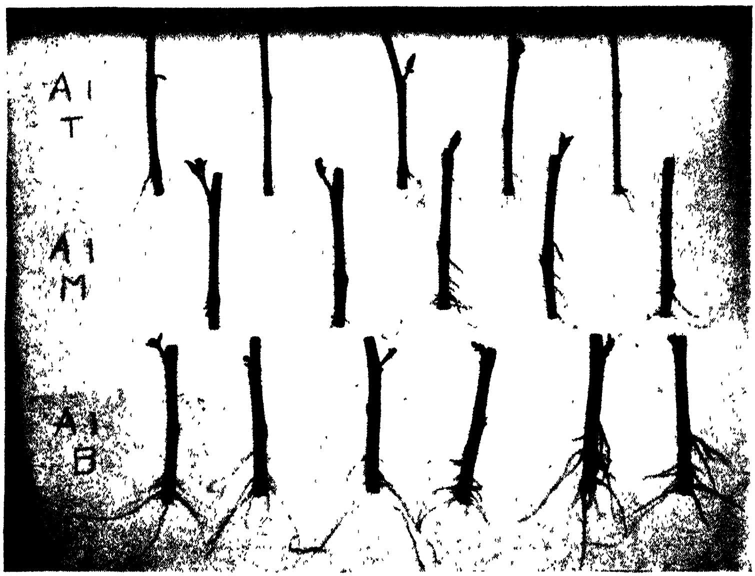

PLATE VI. Cuttings from non-vegetative plants showing largely a regeneration of roots. The letters T, M and B refer to the tip, middle and base, respectively, of the plant.

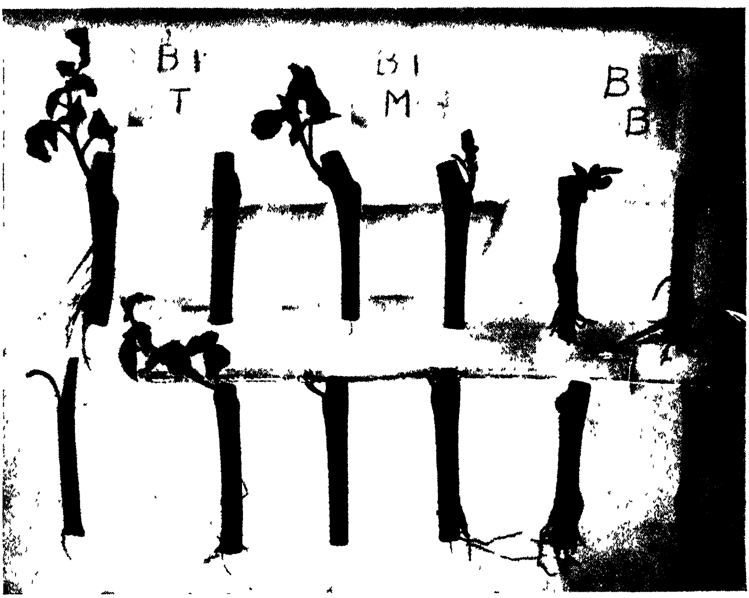

PLATE VII. Cuttings from vegetative plants showing largely a regeneration of tops. The letters T, M and B refer to tip, middle and base, respectively, of the plant.

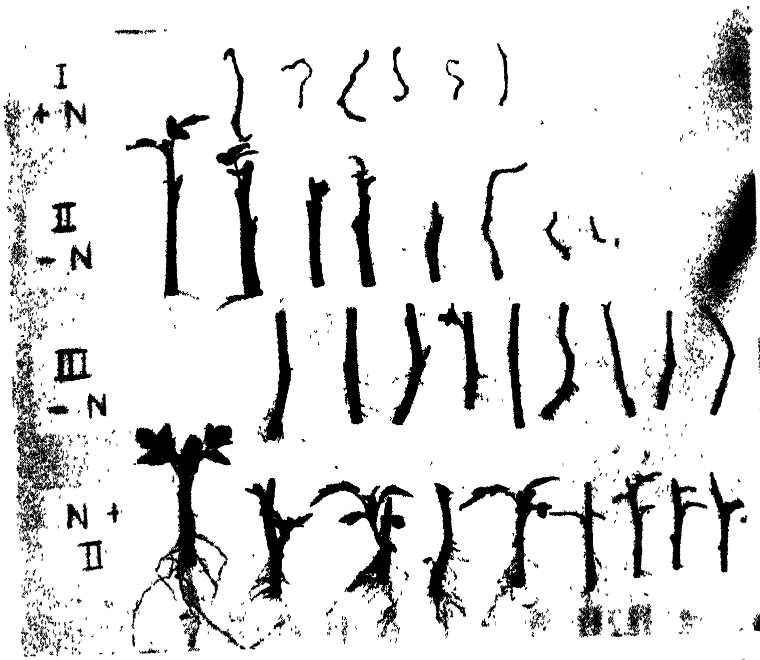

PLATE VIII. Row 1.—Extremely vegetative material plus nitrates. Row 2.—Extremely vegetative material without nitrates. Row 3.—Extremely non-vegetative material without nitrates. Row 4.—Extremely non-vegetative material plus nitrates.

At the end of six days, small shoots appeared on the tip and middle cuttings, but no roots were present. Neither roots nor shoots had started on the basal cuttings. Two days later the basal and middle cuttings had regenerated a few roots, but none had appeared on the tip cuttings.

After 15 days, the tip cuttings possessed a few small roots and had shoot growths of about one inch. The middle cuttings had several good roots and shoot growths of about one inch. The basal cuttings had developed a good root system, but no shoot had appeared as yet. A slight shoot growth started at the end of 19 days.

At the end of 24 days the cuttings as a whole showed a strong regeneration of shoots and relatively few roots. The tip cuttings showed the most shoot growth; the middle cuttings were intermediate, and the basal cuttings possessed the least shoot growth. The shoot growth on this material was then in inverse relation to the carbohydrate gradient in the plant. The greatest root growth appeared on the basal cuttings, which appears to be related to the presence of root primordia which occurred at this point of the plant. The middle and tip cuttings showed very little root growth. (Plate VII).

The microchemical tests which were made at frequent intervals on sample cuttings from each lot showed a great decrease in starch and especially in protein material.

The above experiments on vegetative material indicate that the growth of shoots on tomato cuttings is dependent on the presence of available nitrogen in the cuttings. This available nitrogen probably exists as water-soluble nitrogen, as is indicated by the high nitrate content of the vegetative material. (See Table I). Shoots appeared first on the tip cuttings which contain the greatest supply of nitrates, since there is a gradient of nitrates from the tip of the plant to the base. The basal cuttings required 19 days to develop shoots, whereas shoots appeared on the tip cuttings in six days.

From the preceding experiments on material widely varying in chemical composition, it appears that a high carbohydrate supply coupled with a relatively low supply of available nitrogen, will result in the development of roots on tomato cuttings, while shoot production is much restricted. On the other hand, a high available nitrogen supply coupled with a low supply of carbohydrates, will result in the production of shoots and little or no roots. An abundant supply of both carbohydrates and available nitrogen results in both shoot and root development.

Cuttings from Extremely Vegetative Material With Very Low Carbohydrate and Relatively High Nitrogen Content

The succulent growth which occurs as "suckers" in the axils of the petioles of tomato leaves was selected for use as cuttings. Microchemical tests showed this material to be very low in starch and reducing sugars and very high in nitrates. The lot of cuttings was divided into two sets; one set to receive an external supply of nitrates, and the other set to have no nitrates supplied.

Plus Nitrates: These cuttings were placed in white quartz sand in a ten inch pot to which was added 175 cc. of 1.6 per cent solution of calcium nitrate following the addition of tap water which saturated the sand. The results obtained from these cuttings plus nitrates, is shown in Plate VIII, in the top row of cuttings. The cuttings all failed to regenerate either roots or shoots and soon decayed.

No Nitrates Added: These cuttings were also planted in white quartz sand lacking nitrogen. The second row of cuttings on Plate VIII shows the regeneration which resulted. The cuttings are arranged in the picture according to diameter of the piece with the thickest cuttings at the left.

The larger cuttings at the left produced only shoots which agrees with the results of the experiments on vegetative material previously outlined.

The amount of shoot growth in the series appears to be in direct relation to the size of the cutting, that is, the larger cuttings made the greatest shoot growth, but it is probably also true that the larger cuttings possessed the greater amounts of carbohydrates.

The smaller cuttings at the right with probably less carbohydrate content failed to regenerate either roots or tops which corresponds to the results on similar material plus nitrates.

These results on this extremely vegetative material indicate the necessity of a supply of carbohydrates for regeneration of either roots or tops, or, in other words, when carbohydrates are practically lacking, no regeneration can result.

Cuttings From Extremely Non-Vegetative Material High in Carbohydrates and Very Low in Available Nitrogen

These cuttings were made from plants which had been grown several weeks in quartz sand without nutrient, and hence the plants had thin, stiff stems of a grayish green to yellowish color, and possessed only a few small upper leaves of a yellow color. Microchemical tests showed a very low nitrate content and a high starch content. One-half of this lot of cuttings were supplied with a 1.6 per cent solution of calcium nitrate and the other half received no nutrient. Both sets of cuttings were placed in white quartz sand as in the other experiments.

Plus Nitrates: The bottom row of cuttings on Plate VIII shows the regeneration which occurred on these cuttings. In general, an abundant regeneration of both shoots and roots resulted, but there also appears to be a relation within the lot between the diameter of the cutting and the amount of growth produced.

No Nitrates Added: The growth which was regenerated on those cuttings is shown in the third row from the top in Plate VIII. Few roots resulted in contrast to the abundant regeneration of roots on similar material to which an external supply of nitrates was added. However, it must be noted that only roots were regenerated from this high carbohydrate material and this result was also found in the experiments previously outlined. The cuttings in this lot evidently

lacked sufficient available nitrogen to utilize the carbohydrates in growth.

Discussion

The foregoing experiments show a fairly definite relation between the chemical content of a tomato cutting and the kind and amount of regeneration which results from such cuttings, that is, with a favorable supply of moisture, oxygen and light. If the soluble nitrogen is practically lacking, as in the case of feebly vegetative plants high in carbohydrates, root regeneration is correspondingly lessened even though carbohydrates are present in large amounts. Shoot growth is practically inhibited under such conditions. Increasing the supply of soluble nitrogen, although relatively low, either within the plant or outside it, in the presence of a large amount of carbohydrates, will result only in an abundant regeneration of roots. However, further increasing the quantity of soluble nitrogen by external supply in such material high in carbohydrates will result in abundant regeneration of both roots and tops. Thus a cutting from non-vegetative material high in carbohydrates will regenerate in varying manner and degree depending on the supply of soluble nitrogen.

On the other hand, if the supply of carbohydrates is practically lacking, as in the case of very succulent tissue, no regeneration of either roots or tops will result even though soluble nitrogen is present in abundance. Decay of such cuttings follows. An increase in the supply of carbohydrates although relatively low in relation to soluble nitrogen, will favor shoot regeneration, and practically no root regeneration. Cuttings from vegetative material, high in soluble nitrogen will thus regenerate only shoots, or if carbohydrates are lacking, no regeneration occurs and decay follows. An increase in carbohydrates in such material brings us again to the condition previously stated, which favors abundant regeneration of roots and tops on cuttings.

Conclusions

1. High carbohydrate content of tomato cuttings plus a relatively low supply of soluble nitrogen favors the regeneration of roots.
2. High carbohydrate content, as in (1) plus a decreased supply of soluble nitrogen, compared to (1), lessens root regeneration as compared to (1).
3. High carbohydrate content, as in (1), plus an increased supply of soluble nitrogen compared to (1), results in abundant regeneration of both roots and tops.
4. Low carbohydrate content plus a relatively high supply of soluble nitrogen favors the regeneration of tops, in contrast to (1).
5. With carbohydrates practically lacking, plus a high supply of soluble nitrogen, as in (4), neither root or top regeneration occurs.
6. There appears to be a definite quantitative relation between the volume of a cutting and the resulting regeneration within a given lot of material similar in chemical constitution.

7. Organic nitrogen is evidently utilized in the growth of tops.
8. Rapid accumulation of starch and depletion of nitrates, as such, occurs in the tomato plant when deprived of an external supply of nitrates.

Recent investigations by Mary E. Reid (1), (2) and C. C. Starring (3) on cuttings of the tomato are in general agreement with the results detailed in this paper.

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The Chemical Composition of Developing Flowers and Young Fruits from Weak and Vigorous Spurs of the Apple

By F. S. Howlett, *Ohio Agricultural Experiment Station, Wooster, Ohio*

THE WRITER presented evidence in 1923 based upon chemical analysis of the developing flowers and young fruits of the apple which showed the comparatively large amounts of total nitrogen and carbohydrates in these parts of a tree. The purpose of those analyses was to obtain absolute as well as relative values for the amounts of the various growth materials which are translocated into the flower during its development.

It is possible that insufficiency of food material, either in quantity or in proper form, may be a limiting factor to fruitfulness.

It is well known that the addition of nitrogen to trees growing under certain conditions increases the set of fruit. May it not be possible, therefore, that either the supply necessary to develop the flower up to full bloom, with all parts functional, is insufficient in absolute or relative amounts, or else there is a lack of the element in the proper form for normal growth and development? Slightly unfavorable

nutritional conditions before the flower has reached the stage when it would be fertilized may result in degeneration of certain of its essential parts.

Harvey (1) has shown the importance of sufficient leaf area for the setting of fruit of the apple. It is readily conceivable that with the very rapid growth of the flower prior to full bloom and of the young fruit after fertilization that large amounts of carbohydrates and nitrogen are absolutely essential if these changes, which result in abscission, are not to occur.

The writer's paper (3) in 1923 gave analytical data showing the nitrogen and carbohydrate composition of flowers and young fruits from healthy, vigorous spurs taken from 13 year old trees of Roxbury Russet. This paper will present data obtained by analysis of flowers taken at two different stages in their development from weak and vigorous spurs of the variety Fall Pippin.

The flowers from the weak spurs of a tree are smaller than those from vigorous spurs. There is also a greater fall of flowers at the "first drop" from weak spurs than from vigorous spurs which have a greater diameter and length. These vigorous spurs are, no doubt, more capable of storing and translocating food and conducting water than weak spurs. The question arises, therefore, as to whether there might be any significant differences upon the green and dry weight basis in the amounts of the various nutritive materials present in the flowers from weak spurs and from vigorous spurs. It is obvious, of course that the larger flowers would probably have greater absolute amounts of nitrogen and carbohydrates.

The flowers were collected by Dr. A. J. Heinicke in 1920 from some partially neglected trees growing under sod conditions in one of the departmental orchards in Ithaca. When the writer became interested in the subject of flower nutrition, the material was very kindly turned over to him for chemical analysis and interpretation.

Methods of Analysis

The material was preserved in alcohol and extracted according to the procedure necessary with material so preserved. The Official Methods of the A. O. A. C. were used for analysis.

Presentation of Data

The flowers were collected May 22, from two trees of Fall Pippin. One-hundred gram samples from each type of spur were taken for analysis. The central flower of each cluster was about to open while as yet no laterals were enlarged sufficiently to expose the stamens. The average weights of the flowers of an individual spur and of the cluster bases without flowers and leaves are given in Table I.

No counts were made of the flowers at the time of the first two collections, but the approximate average number of flowers on a single spur has been calculated by using the value of 5.8 for each spur. This number was the average determined by actual counts of over a

thousand spurs of three varieties. It is realized that the individual weak spur may have had fewer flowers on the average than an individual vigorous spur, but the difference would not be great enough to change materially the ratio of the absolute amounts in the flowers from each type of spur.

TABLE I.

Type of	Number of flower clusters removed	Total Weight of flowers (grams)	Weight of flowers per cluster (Milligrams)	Weight of cluster base (milligrams)
Vigorous....	200	219.5	1097.5	98
Weak.. .	300	238.5	795.0	48

The data from the chemical analysis at this stage is presented in Table II. The values are expressed in average total amounts in an individual flower as well as in percentages of green and dry weight.

An examination of the data indicates that the average total amounts of nitrogen, free reducing substances, total sugars and the acid hydrolyzable polysaccharides are greater in the flowers from vigorous spurs than the flowers from weak spurs. This would be expected from the greater weight of the vigorous flowers. However, on the basis of both green and dry weight there are no significant differences between the flowers from the two types of spurs.

Flowers were taken May 30 from weak and vigorous spurs of the same two trees. Composite samples were made of the flowers from the vigorous spurs and also of the flowers from weak spurs. One-hundred gram lots of each were taken for analysis. The petals had just fallen. Certain flowers had, no doubt, been fertilized and were capable of further development while others were not. However, as yet there were no differences in size between the individual flowers on the spurs. The data are presented in Table III.

The same relationship in absolute amounts of nitrogen and carbohydrates existed between the individual flowers from the spurs of different vigor. Moreover, on the basis of green and dry weight, there were no significant differences between the two sets of flowers.

A collection was made on June 2, of flowers from spurs of the same trees of Fall Pippin. At this time the lateral flowers, in many cases, were showing a slight yellowing or had abscised. One-hundred grams of lateral flowers which were about to abscise but showed no yellowing, and 100 grams of lateral fruits which were persisting were collected from the same spurs. More flowers were about to abscise from the weak spurs than from the vigorous spurs. The flowers and young fruits were taken irrespective of the type of spur, and the number of flowers in each sample were counted. The data are given in Table IV.

The lateral fruits which are persisting are much larger and contain greater average total amounts of nitrogen but less total sugars. On the basis of green weight those flowers which will abscise have less moisture, practically the same percentage of nitrogen, but con-

siderably more free reducing substances and total sugars. On the basis of dry weight those which will remain have more nitrogen, but ess free reducing substances and total sugars. The data from this. vlariety follow very closely that of Roxbury Russet presented in 1923

Discussion of Data

An analysis of the analytical data given indicates that there were no significant differences as far as total nitrogen and carbohydrates are concerned between the flowers from vigorous and from weak spurs. It should be kept in mind that the collections were made at two stages, (1) while the flowers were rapidly enlarging and (2) just as the petals had fallen. Those changes, which would result very shortly after petal fall in rapid growth and enlargement of certain flowers, had occurred so recently that superficial examination could not detect to which ones thay had occurred. If a comparison is made between the average total amounts of nitrogen and carbohydrates in the flowers just as the petals have fallen and the amounts present in those flowers which will fall at the "first drop" it is evident from the data presented in 1923 as well as that given here that no increases have occurred after the petals have fallen in those flowers which will shortly abscise. In other words, had the flowers been capable of further development after the petals had fallen, growth and enlargement would have occurred. We may reasonably assume, therefore, that the factor responsible for the ultimate fall of the flowers had its effect previous to petal fall. In the majority of cases, such flowers have probably not been fertilized. As pointed out previously by Heinicke (2), and as observed by other workers, there is a greater abscission of flowers from weak spurs at the "first drop" than from vigorous spurs. Unless we assume unequal pollination between the two sets of flowers, it is probable that many of the flowers from weak spurs are incapable of being fertilized because of some changes which have taken place previous to full bloom. What these changes are we can only surmise. Whether they are related to egg cell degeneration resulting from inadequate nutrition of the flowers has not been established.

However, we are fully aware of the favorable influence of inorganic nitrogen added before bloom upon the setting of fruit. Whether its effect is through increasing the total quantity of nitrogen present or through increasing the supply of a particular form of nitrogen necessary for adequate nutrition of the flowers, is not known. As yet certain relationships must be worked out before we can come to a conclusion in this matter.

Bibliography

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Analysis of Flowers from Vigorous and Weak Spurs—Fall Pippin—1920

Table	Nature of material	Date	Number of flowers	Basis of single flower: Green weight (milligrams)	Dry weight (milligrams)	Total nitrogen (milligrams)	Free reducing substances (milligrams)	Total sugars (milligrams)	Acid hydrolyzable polysaccharides (milligrams)	Percentage of green weight: Dry matter	Total nitrogen	Free reducing substances	Total sugars	Acid hydrolyzable polysaccharides	Percentage of dry weight: Total nitrogen	Free reducing substances	Total sugars	Acid hydrolyzable polysaccharides
TABLE II	Flowers from vigorous spurs	May 22	528	189.2	33.2	1.11	2.68	2.82	5.00	17.55	0.585	1.42	1.49	2.64	3.34	8.06	8.50	15.06
	Flowers from weak spurs		730	136.9	25.2	0.82	1.90	2.08	3.66	18.44	0.595	1.39	1.52	2.68	3.23	7.53	8.24	14.51
TABLE III	Flowers from vigorous spurs	May 30	646	154.8	36.4	1.14	3.13	3.39	4.69	23.54	0.736	2.02	2.19	3.03	3.13	8.58	9.28	12.87
	Flowers from weak spurs		720	138.8	32.0	0.96	3.01	2.97	4.07	23.03	0.692	2.17	2.14	2.93	3.00	9.40	9.28	12.70
TABLE IV	Lateral fruits persisting	June 2	481	207.8	46.7	1.52	2.77	3.01	6.34	22.47	0.731	1.33	1.45	3.05	3.23	5.94	6.45	13.58
	Lateral flowers which will abscise		689	145.1	35.4	1.03	2.96	3.70	4.95	24.41	0.710	2.04	2.55	3.39	2.91	8.34	10.44	13.89

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Effect of Various Lengths of Day on Development and Chemical Composition of Some Horticultural Plants

By E. C. AUCHTER and C. P. HARLEY,* *University of Maryland, College Park, Md.*

INTRODUCTION

THE importance of the effects produced by varying the duration of daily light (length of day) upon the vegetative and reproductive activity of different species and varieties of plants has recently been emphasized by the work of Garner and Allard (1), (2), (3). These investigators have shown that certain species of plants blossom readily when subjected to short days (seven to 12 hours), while others blossom only when subjected to long day conditions. The first group of plants are known as "short day" plants, while the second group are termed "long day" plants.

In the first group, the plants will blossom even under the influence of very short days, while in the second group flowers will be developed even with extremely long days. A third group of plants was found, however, which seemed to occupy an intermediate position, that is, certain plants in this group would not blossom if the length of day was either too long or too short.

Other investigators, including particularly the work of Kraus and Kraybill (4) have shown that the relation of the carbohydrate content of plants to the amounts of nitrogen available strongly influences their vegetative and reproductive responses. Thus an increase or decrease of either of these materials in relation to one another, might cause various degrees of growth, or reproduction, or both.

In view of the researches of these different authors, the writers were interested in determining, if possible, some of the internal chemical differences, especially the carbohydrate and nitrogen contents of groups of plants growing under varying lengths of day and subjected also to different amounts of nitrate applications.

OUTLINE OF EXPERIMENTS

Plants Used: Experiments were started in 1923 with Biloxi soy beans and Ruby King peppers on June 17 and 18 respectively, and with Grand Rapids lettuce and White Icicle radishes on June 17 and July 3 respectively. These plants were grown in wooden boxes,

*Mr. F. S. Lagasse, a graduate student, also assisted in conducting certain phases of this problem.

10 inches deep, 11 inches wide and 18 inches long. A series of boxes known as "high nitrate" and another known as "low nitrate" were used with each of the plants under all the different light conditions.

Soils and Nitrates Used: The "high nitrate" boxes were filled with a soil composed of two-thirds loam and one-third manure, which had been previously composted. The "low nitrate" boxes were filled with bank sand of comparatively low fertility.

A nutrient solution containing nitrates was added to the "high nitrate" series and a nutrient solution lacking nitrate was added to the "low nitrate" series at two weeks intervals during the experiments. Five hundred cc. of the solutions were added at each date after the first application. The plants being small at that time, only 50cc. of the solutions were added to each box.

In addition, tap water was added regularly to keep the soil moisture content uniform and suitable for plant growth.

Duration and Intensity of Light: With peppers and soy beans nine different plots, varying in regard to amounts and intensities of light received as shown in Table I were used. With lettuce and radish, four different plots as shown in Table II, were used.

The normal day plants were simply left out doors day and night by the side of the dark house.

The dark room used was eight feet wide, 20 feet long and six feet high. The walls and ceiling were covered with black cloth. Arrangements were made in the side for ventilation. An electric fan was operated continuously as an aid in ventilation, and in improving the temperature and humidity conditions.

Those plants (plot seven) which received electric light at night, were placed out doors during the day. The electric light room was eight feet wide, eight feet long and six feet high. One 150 watt nitrogen filled tungsten Mazda light was arranged in the ceiling of the room. The door leading to the outside of the room was closed at night, only with a dark drop curtain. This allowed for ventilation.

In those plots, out of doors, which received shade, standard cheese cloth was added as a covering. This reduced the maximum intensity of the direct light reaching the plants to about 43 per cent of the normal (1).

Temperature and Humidity Conditions: No special arrangements, other than those described above, were used to control humidity and temperature in the different rooms. Temperature and humidity records were obtained, however, every two hours each day, both inside and outside the different rooms.

The continuous dark room fluctuated slightly, but as a whole averaged, during the day, 5° cooler inside and 15 per cent more humid than the outdoors. No special floor was made in the dark room. It was a clay loam soil, tightly packed.

The electric light room averaged 1½° warmer inside than the outdoors at night. It was also three and one-fourth per cent more humid. The electric light room was about 2° warmer than the dark room at night.

The cheese cloth shade over the boxes outside was so arranged that the temperature and humidity inside varied little from outside conditions.

These slight differences in temperature and humidity under the different conditions apparently did not influence the time of flowering as seen by the different tables.

Responses of Plants Under Different Light and Nutrient Conditions

Reference to Tables I and II show that the different plants in the "high nitrate" series responded approximately the same to different amounts of light, as did those of Garner and Allard (1). Soy beans clearly were "short day" plants, while lettuce and radishes fell into the "long day" class. The peppers, however, apparently were not so markedly influenced within the light limits used un these experiments. Those subjected to a light duration of 12 hours blossomed earlier (34 days), but the normal day plants blossomed in 37 days the same as did the seven hour plants. The normal day plus electric light plants blossomed in 49 days, while the broken day plants blossomed in 34 days. Likewise the height of the plants in the different plots of peppers did not vary as much at blossoming time as did the heights of the three other plants used.

The broken day plots, although receiving sunlight equivalent in amount to the short day plants, did not blossom until after the normal day plants. Thus duration or continuation of the light is necessary if a certain response is to be obtained.

The cheese cloth shade over the soy bean plants did not affect the time of blossoming although the shaded plants were taller at blossoming. Whether the plants were in the dark from 10:00 A.M. to 2:00 P.M. (Plot IV) or in the strong sunlight during these hours (Plot VIII), the time of blossoming and the height of the plants were about the same in the two cases. Thus in these cases, intensity of light within the limits used, did not seem to affect the time of blossoming.

With peppers, the cheese cloth shade did not affect the time of blossoming of the normal day plants in the "high nitrate" series. In the "low nitrate" series of the normal day plants, the shade seemed to delay blossoming and the height of the plants was greater at blossoming time. The shade delayed blossoming slightly in the seven hour day "high nitrate" series, but not in the "low nitrate" series.

Effects of Nitrate Applications: In the case of soy beans, very little difference was noted in the response of the "high" and "low" nitrate series. Each of the series was affected similarly by a certain length of day. The high and low nitrate plants also appeared very similar in color and growth. These results can probably be largely explained by the fact that soy beans, being leguminous plants were able to obtain sufficient nitrogen for satisfactory growth even in the sand boxes and when nitrates were not added to the nutrient solution.

Similar examples can be seen by studying Tables I and II.

TABLE I

Influence of Length of Day and Intensity of Light on Vegetative and Reproductive Activity in Biloxi Soybeans and Ruby King Peppers

Plot	Amount, Duration and Intensity of Light	Amounts of Nitrogen	Number of Days Before Blossom-Bud Formation		Number of Days Before Blossoming		Height of plant at time of Blossoming	
			Soybean	Peppers	Soybean	Peppers	Soybean	Peppers
I.	Normal Day, 15 hours.	H.N.	82	27	86	37	32	15
		L.N.	82	64	87	73	31	6
II.	Sunlight from 9 A. M. to 4 P. M., 7 hours.	H.N.	28	27	32	37	14	15
		L.N.	29	87	32	TT	14	6
III.	Sunlight from 6 A M. to 6 P. M., 12 hours.	H.N.	28	27	31	34	16	12
		L.N.	28	64	31	70	15	6
IV.	Daylight to 10 A. M. and from 2 P. M. to dark, 8½–11 hours	H.N.	93	31	95	43	25	10
		L.N.	93	**	95	**	25	**
V.	Same as Plot II but shaded with cheese cloth, 7 hours.	H.N.	28	31	31	43	15	17
		L.N.	28	71	31	75	15	8
VI.	Same as Plot I but shaded with cheese cloth, 15 hours	H.N.	84	27	87	36	42	15
		L.N.	85	64	88	90	40	11
VII.	Normal day plus electric light at night, 24 hours.	H.N.	*	36	*	49	*	13
		L.N.	*	66	*	97	*	8
VIII.	Broken day in darkness from 9 to 11 A. M. and from 2 to 4 P. M. 8½–11 hours.	H.N.	90	T	92	T	26	T
		L.N.	90	T	92	T	25	T
IX.	Normal day for 30 days, then 7 hour day.	Double amounts of Nitrates	69	T	73	T	24	T

*This plot was carried in the experiment for 160 days, but showed no indication of blossoming at the end of that time. The plants, however, continued to increase in length.

**Did not blossom at the end of 87 days. T Experiments with peppers not conducted. TT Blossom buds fell off before opening.

NOTE: All experiments on soybeans were started June 17, plants were three inches in height. All pepper experiments started June 18, plants were about two inches in height.

Blossoms in plot four did not set fruit. This plot continued to increase in height after blossoming.

GROWTH AND APPEARANCES OF DIFFERENT PLANTS

Soy Beans: On July 11, 24 days after starting the experiments, the foliage of the seven and 12 hour day plants was smaller and lighter than the normal day plants. The stems likewise were not as thick. These plants were 11, and 11½ inches high respectively and the normal day plants were 12 inches in height. The broken day plants were also light in color, 11 to 12 inches tall, the foliage was small and the individual leaves were very thin. The shaded plants in the seven and 15 hour plots were 13 and 17 inches high respectively. The foliage was about the same as the unshaded seven and 15 hour plots, except that the leaves were slightly larger. The electric light plants were 18 inches high with healthy, large and dark green foliage.

On July 19, 32 days after starting the experiments, the seven and 12 hour day plancs were blossoming. Their heights were 14 and 16 inches respectively. The foliage was a lighter green than the normal day plants and the individual leaves were smaller. The normal plants were vigorous, 20 inches high and showed no signs of blossoming. The broken day plants were 16 inches high, light green in color and the leaves themselves were very thin. The electric light plants were 26 inches high, very vigorous and with very large, dark green leaves. The seven hour day shaded plants were 15 inches high and the foliage was slightly larger than the seven hour unshaded plants, though the foliage was light green. These plants were flowering. The normal day shaded plants were 24 inches high, dark green in color, large sized leaves and showed no signs of flowering.

On August 9, 53 days after starting the experiments, the normal day plants were 27 inches high, the seven and 12 hour day unshaded plants were 14 and 16 inches, the seven and 15 hour day shaded plants were 15 and 32 inches, the broken day plants were 20 inches and the electric light plants were 30 inches in height. Foliage comparisons were about the same as the July 19 records, except that the leaves of the normal and electric light plants were now larger.

On September 13, 88 days after starting the experiments, the normal day plants were now 32 inches high, dark green in color and were blossoming. The seven hour and 12 hour day plants had not increased in height over the August 9 date, but the seeds had matured. The leaves were light in color and the plants were yellowing in appearance. More and better developed pods were noticeable on the 12 hour day plants. The broken day plants were 25 inches in height, the stems were slender and the individual leaves were lighter green and thinner than the normal day plants. Blossom buds had not yet formed but these plants did blossom from four to seven days later. None of the blossoms "set" however, and no beans were matured. Seed was matured on the seven hour day shaded plant while the normal day shaded plants were just beginning to blossom. These plants were then 42 inches in height. The electric light plants had large dark leaves at this time and were 42 inches high.

From about the middle of August the normal day shaded plants and the electric light plants began to assume a sprawling habit and

TABLE II

Influence of Length of Day and Intensity of Light on Vegetative and Reproductive Activity in Grand Rapids Lettuce and White Icicle Radish

Plot	Amount, Duration and Intensity of Light	Amounts of Nitrogen	Number of Days Before Blossom Bud Formation		Number of Days Before Blossoming		Height of plant at Time of Blossoming		Height at End of Experiment
			Lettuce	Radish	Lettuce	Radish	Lettuce	Radish	Radish
I.	Normal Day, 15 hours.	H.N.	36	21	65	26	30	21	—
		L.N.	87	T	TT	T	TT	T	5
II.	Sunlight from 9 A. M. to 2 P. M., 5 hours.	H.N.	*	T	*	T	*	T	6
		L.N.	*	T	*	T	*	T	2
III.	Sunlight from 6 A. M. to 4 P. M., 10 hours.	H.N.	67	60	83	62	29	17	—
		L.N.	TTT	T	TTT	T	TTT	T	2
IV.	Normal day plus electric light at night, 24 hours.	H.N.	42	26	59	37	40	35	—
		L.N.	69	T	87	T	27	T	4

*These plants grew very poorly and were diseased. They were practically all dead after three weeks.
T: No blossoming had occurred after 75 days when experiment was discontinued.
TT: No blossoming had occurred after 87 days when experiment was discontinued. Plants were nine inches high.
TTT: No blossoming had occurred after 87 days when experiment was discontinued. Plants were six inches high.
NOTE: The lettuce experiments were started on June 17th except plot II, which was started on June 27. The radish experiments were started July 3.

at this date (September 13) did not have as upright growth as the unshaded normal day plants, but were more vine-like in appearance.

The plants in plot nine (normal day plus double amounts of nitrate) were subjected to a normal day for 30 days and were then placed under seven hour day conditions. These plants then blossomed in 39 more days, or a total of 69 days, which was much less than the time required for the normal day plants in plot one.

Peppers: The "high nitrate" series grew much faster and had a larger and darker green foliage than the plants in the "low nitrate" series. This occurred in all plots. On July 11, 23 days after starting the experiment, the "high nitrate" plants were approximately twice as high as the "low nitrate" ones. The "high nitrate" plants were about eight inches tall in the normal and short day groups, six and one-half inches tall in the broken day and short day plus shade, nine inches tall in the electric light groups and 11 inches in the normal day plus shade plants. The "low nitrate" plants were all about four inches tall except the electric light plants, which were six inches in height.

On July 19, 31 days after starting the experiments, the plants in all plots of the "high nitrate" series except the electric light group, were forming blossom buds. The plants were all vigorous and the foliage dark green. At this time the plants in the different groups were between 12 and 13 inches in height. The broken day plants were not quite as tall and vigorous as the others, and were not forming blossom buds so freely. The "low nitrate" plants still remained small (four to six inches) in all of the plots, were rather yellow in color and showed no signs of forming blossom buds.

On August 9, 52 days after starting the experiments, the normal day plants, seven and 12 hour day plants, and the normal day plus shade plants, had been, and were all setting fruit in the "high nitrate" series. The broken day plants, seven hour day plus shade and electric light plants, had not yet set any fruit. The 12 hour day plants set more profusely than any of the others. The "low nitrate" plants had not blossomed in any of the plots and were only one-third to one-half as tall as the "high nitrate" plants.

On September 13, 87 days after starting the experiments, the 12 hour day plants were 15 inches tall and had the best set of fruit. The fruit was much more mature in this plot than in any of the others. The normal day and seven hour day plants were 19 and 18 inches high, respectively, and were maturing fruits. The broken day plants were 17 inches high, but the fruits were not as plentiful or as matured as in the other plots.

The shaded plants (plots five and six) still had some blossoms and the fruits were not as numerous or mature as the 12 hour day plants.

The "low nitrate" plants in the normal day plot had blossomed and some plants were setting fruits. The plants were eight inches high. The seven hour day plants formed blossom buds at this time, but they did not set. The 12 hour day plants had blossomed after 70 days, but did not set fruit. The broken day plants did not blossom.

The short day plants plus shade blossomed but did not set. These plants were nine inches tall. The normal day plus shade plants blossomed in 90 days.

In the pepper experiments, the cheese cloth shade did not affect the time of blossoming of the normal day plants in the "high nitrate" series. In the "low nitrate" series of the normal day plants, the shade seemed to delay blossoming. The shade delayed blossoming slightly in the seven hour day "high nitrate" series, but not in the "low nitrate" series.

Lettuce: On July 11, 24 days after starting the experiments, the five hour plants in both the "high and low nitrate" series, and the electric light plants, were larger and had broader leaves with better color than those in any of the other plots, the normal day plants were the next largest followed by the 10 hour day plants. The "low nitrate" plants in the 10 hour day series were small, weak, and poor in color. The normal day plants were small and light in color, while the electric light group were small, but in good growing condition.

On July 19, the electric light plants in the high nitrate series were the most vigorous, followed by the normal day and then the 10 hour day plants. The low nitrate series were stunted in appearance. Reference to Table II shows that the electric light plants blossomed in 59 days, the normal day plants in 65 days and the 10 hour day plants in 83 days. The "low nitrate" plants in the electric light plot were the only "low nitrate" plants to blossom. It is interesting to note that the time of flower bud formation was about the same in the case of the "low nitrate" electric light plot and the "high nitrate" 10 hour day plot. The intervals between the time of flower bud formation and blossoming were about the same in both of these plots. Likewise the height of plants at blossoming time was about the same. The measurements of the heights at blossoming are given in the table.

Radishes: After 16 days in the experiment, the electric light plants, in the "high nitrate" series, had the largest leaves and the plants were the tallest (nine inches). These were followed by the normal day plants (eight inches) and then the 10 hour day group (seven inches). The five hour day plants were very sickly and were only four inches tall. The petioles in all "high nitrate" plants were green, while those in the "low nitrate" series were red. The "low nitrate" plants were all under two inches in height.

In the "high nitrate" series, the electric light plants blossomed in 37 days at which time the flower stems were 40 inches high, the normal day plants in 26 days at a height of 30 inches and the 10 hour day plants took 62 days and were 29 inches tall. The five hour day plants had not blossomed after 75 days, when the experiment ended. The electric light plants were taller and had larger and greener leaves than the normal day plants. The normal day plants were followed by the 10 hour day group. The "low nitrate" plants did not blossom during the experiment. They remained small with yellowish green foliage.

On September 15, 75 days after starting the experiments, the plants were dug and the roots examined. The roots were very small and undeveloped in the five hour day plants. The 10 hour day plants which had not made such a rapid top growth, and which blossomed late, had the largest roots. The 15 hour day plants were next in size, followed by the electric light plants. Thus, although the 15 hour day plants and the electric light plants grew more rapidly and blossomed earlier, the soluble carbohydrates were probably used mostly in top growth and less of them were translocated and used in developing root growth.

Chemical Analysis of Soy Beans in the Different Plots

Unfortunately, it has been impossible to complete the analyses of all the different plots of soy beans at this date. Likewise the analyses of the peppers, lettuce, and radishes have not been completed. As a result the analyses of only four plots of the "high nitrate" soy beans are presented at this time.

Methods of Analysis: Samples for chemical analysis were taken on clear, bright days between 10:00 A.M. and 2:00 P.M. Plants for analysis were cut off at the surface of the soil and taken immediately to the laboratory where fresh weights were obtained. The number of plants per sample varied somewhat, depending upon the date of sampling and size of plants, the average sample consisted of approximately 17 plants. Leaves and stems were separated and preserved separately by covering them with enough 95 per cent alcohol to bring the total concentration to about 70 per cent assuming the tissue contained 75 per cent moisture. Exactly .25 gram of calcium carbonate was then added to neutralize any acid which might be present. The flasks containing the samples were then placed in a water bath maintained at 70 degrees C. and refluxed for a period of one hour to arrest any enzymatic action.

In preparing the material for analysis the alcoholic extract was filtered off, and the solid matter dried in an oven at 80°C. for 48 hours. At the end of this time the dried residue was weighed, for oven dry weight, and then ground to pass through a 100 mesh sieve. Suitable aliquots were now taken from the powdered residue and again extracted with 50 per cent alcohol in Soxhlet extraction tubes for three hours. The alcoholic solutions from this extraction were added to a corresponding aliquot from the original preserving alcoholic extract and analysis conducted. Analysis was also made of the powdered residue after the alcoholic extraction.

All sugar determinations were made according to the method of Munson and Walker as modified by Bertrand.

Reducing Sugars: An aliquot of the combined alcoholic extractions was cleared with neutral lead acetate. The cleared solution was then taken without further treatment to determine its reducing power. Results were calculated as glucose.

Total Sugars: The aliquot of the cleared solution was hydrolyzed by means of a five per cent Hcl solution for 24 hours at room

temperature. The result of this hydrolysis was calculated as invert sugars.

Total Polysaccharides: An aliquot of the insoluble residue was hydrolyzed by boiling under a reflex condenser in a ten per cent Hcl solution for two and one-half hours. The mixture was then neutralized with anhydrous sodium carbonate and the reducing power determined.

Starch: An aliquot of the insoluble residue was taken for the determination of starch.

The method used here is that of Walton and Coe (6) of the Bureau of Chemistry, United States Department of Agriculture, with the exception that commercially prepared malt diastase was used instead of the ground barley grain. A blank was run with each set of determinations and the corrections made for the sugars which were present in the diastase extract.

Soluble Nitrogen: Nitrogenous substances present in the combined alcoholic extracts were determined by the Kjeldahl method modified to include nitrates.

Insoluble Nitrogen: Nitrogenous substances present in the residue which are insoluble in hot and cold alcohol were determined by the Kjeldahl method modified to include nitrates.

Total Nitrogen: The percentage of total nitrogen was calculated by combining the percentage of soluble and insolúble nitrogens.

RESULTS OF CHEMICAL ANALYSES

As previously stated, so few analyses have been made that there is no attempt at this time to draw conclusions relative to the effects of the different lengths of day on the chemical composition of the plants. When the analyses are completed of the remaining soy bean plots and also the different plots of peppers, lettuce and radishes, a safer basis will be had for attempting to draw general conclusions. The analyses are presented so that others may see what the composition is of the plants which have been studied to date.

The composition of the soy bean plants in the "high nitrate" series in the four different plots (plot one—normal day, plot three—12 hour day, plot four—broken day, daylight to 10:00 A.M. and from 2:00 P.M. to dark, and plot seven—normal day plus electric light at night) are shown in table III.

Typical plants were taken from each plot for analyses at four different dates. Thus samples were taken after the plants had been in the experiments 11 days, the second samples after 33 days, the third after 58 days and the fourth after 105 days. The short day plants were flowering at the time of the second sampling. It would have been well if an additional sample had been taken about 85 or 90 days since the normal day and broken day plants were blossoming at about this time. However the relative composition of these

plants probably did not change much before the 105 day samples were taken†.

Thirty-three days after beginning the experiments, (the time of the second sampling), the 12 hour or short day plants were blossoming freely. None of the other plots blossomed before 86 days. It is interesting to note the variation of the chemical composition of the plants in the different plots at this time. It can be seen (table III) that the blossoming, 12 hour day plants, had the highest percentages of reducing sugars, sucrose and thus total sugars. The starch content was much higher than in any of the other plots. These plants also had the highest percentage of total carbohydrates, but the polysaccharides other than starch, were slightly lower than the plants in the other plots. The percentage of total nitrogen was less than in plots one and four, but greater than in plot seven. About 70 per cent of the total nitrogen content was insoluble nitrogen compared to 60 per cent for the broken day plants. The percentages of starch and total carbohydrates in proportion to nitrogen was thus higher for the short day plants. The electric light plants, however, had a slightly higher proportion to nitrogen. In comparing the relation of carbohydrates to the insoluble nitrogen, the short day plants have a higher ratio than any, including the electric light plants. Apparently enough nitrogen was available, however, in the short day plants, so that fair growth was made followed by normal and abundant blossoming.

Nightingale (5) has presented a very interesting and valuable paper in which the proportion of carbohydrates to insoluble nitrogen is shown for various plants growing under different nutrient conditions and lengths of day.

In the short day plants, the stems had a much higher proportion of total sugars than did the leaves. On the other hand the starch content was much higher in the leaves. Most of the soluble nitrogen was found in the stems while the leaves were much higher in insoluble nitrogen.

The normal day plants started blossoming 86 days after the experiments were started. At the fourth sampling date, which was 105 days from the start of the experiments, these plants had about the same composition in comparison to the other plots, that the short day plants had at 33 days, when they were blossoming.

Thus, the plants had higher percentages of total sugars and starch than did the others (of course excluding the short day plants at this time—plot three). The percentage of carbohydrates was also higher and the proportion of insoluble nitrogen to total nitrogen was about the same as in the case of the short day plants. Under the normal day conditions it had apparently taken longer to get these comparable conditions. It is interesting to note that the percentage of total sugars at 105 days is about the same as was the percentage in the short day plants at 33 days. Likewise the percentages of starch and carbohydrate are similar. In these plants most of the starch

†Holmes, M. G. "The Nurtient value of soy beans at various stages of growth," University of Maryland. Unpublished.

TABLE III

Analysis of the Whole Plant of Soy Beans Given in Percentages of Dry Weight

Time of Sampling, Number of Days From Start of Experiment	Free Reducing Sugars				Sucrose				Total Sugars			
	Plot**				Plot				Plot			
	I.	III.	IV.	VII.	I.	III.	IV.	VII.	I.	III.	IV.	VII.
11 Days	1.33	1.17	1.37	1.07	1.72	1.95	1.03	1.32	3.05	2.12	2.40	2.39
33 Days	2.45	*3.02	1.25	2.46	1.24	*1.95	.58	2.10	3.69	*4.97	1.83	4.56
58 Days	1.53	1.58	1.40	3.69	1.27	2.12	1.27	2.70	2.80	3.69	2.67	6.39
105 Days	*2.17	1.37	*1.14	2.30	*2.81	1.94	*.97	2.34	*4.98	3.31	*2.11	4.64

Time of Sampling, Number of Days From Start of Experiment	Starch				Polysaccharides other Than Starch				Total Polysaccharides			
	Plot				Plot				Plot			
	I.	III.	IV.	VII.	I.	III.	IV.	VII.	I.	III.	IV.	VII.
11 Days	2.51	2.20	1.91	1.62	9.65	9.43	7.78	9.32	12.16	11.63	9.69	10.92
33 Days	1.92	*4.32	1.84	1.57	14.03	*13.95	*14.02	14.52	15.95	*18.27	15.86	16.09
58 Days	3.37	10.16	1.58	2.67	15.23	12.61	14.75	15.17	18.60	22.77	16.33	17.84
105 Days	*3.87	7.52	*.95	3.13	*15.52	13.66	*15.51	14.72	*19.30	21.18	*16.46	17.85

TABLE III.—*Continued*

Time of Sampling, Number of Days From Start of Experiment	Total Carbohydrates				Soluble Nitrogen				Insoluble Nitrogen			
	Plot				Plot				Plot			
	I.	III.	IV.	VII.	I.	III.	IV.	VII.	I.	III.	IV.	VII.
11 Days	15.21	13.74	12.09	13.26	2.65	2.87	3.41	3.33	3.47	3 42	2.99	3.09
33 Days	19.64	*23.24	17.69	20.65	.85	*.89	1.60	.45	2.48	*2.16	2.47	2.02
58 Days	21.40	26.45	19.00	24.23	.48	1.09	.55	.48	1.94	1.99	2.13	1.84
105 Days	*24.28	24.49	*18.47	22.49	*.68	1.10	*.51	.46	*1.69	1.60	*2.11	1.54

Time of Sampling, Number of Days From Start of Experiment	Total Nitrogen			
	Plot			
	I.	III.	IV.	VII.
11 Days	6.12	6.29	6.40	6.42
33 Days	3.33	*3.05	4.07	2.47
58 Days	2.42	3.08	2.68	2.32
105 Days	*2.37	2.70	*2.62	2.00

** = Plot I—Nomal Day,
Plot III = Short Day—12 hours,
Plot IV = Broken Day (daylight to 10:00 A. M. and from 2:00 until dark—8½ to 11 hours).
Plot VII = Normal day plus electric light at night.

* = Plot III blossomed in 31 days.
Plot I blossomed in 86 days.
Plot IV blossomed in 95 days.

was in the stems, however, and the percentages of total sugars were more nearly equal in leaves and stems.

The broken day plants (plot four) blossomed in 95 days. The blossoms of these plants, however, did not set. The leaves themselves were very thin as previously explained. The analyses show that in these plants the percentage of sugar was rather low and that the percentage of starch was very low. The percentages of total polysaccharides and carbohydrates were also lower in these plants than in any of the other plots. The percentage of soluble nitrogen was quite low, while that of insoluble nitrogen was higher than in any of the other plots at this time.

These conditions rsulted in a much lower percentage of carbohydrates to insoluble nitrogen than in any of the other plants. The leaves were especially high in insoluble nitrogen while the stems were quite low. Since the blossoms of these plants did not "set" and the stems remained vegetative, it suggests that there was not enough starch and carbohydrates in proportion to insoluble nitrogen to cause satisfactory reproduction.

The electric light plants (plot seven) were still growing vigorously at 105 days, when the last samples were taken for analysis. These plants had not blossomed after 160 days, when the experiments were concluded. At 105 days, although the percentages of sugar and starch were fairly high, still they were not as great in either case as were the plants in plots one and three when they blossomed. This was especially true of the starch. The total polysaccharides and carbohydrates were also slightly lower than the other plots were at blossoming time. The percentage of nitrogen was also lower in these plants than in any of the others. Since these plants continued to increase in length and had the largest sized leaves, it is probable that the soluble carbohydrates were used in extension growth. The lower percentages of starch, polysaccharides other than starch and total carbohydrates, would also suggest this. The proportions of starch and total carbohydrates to nitrogen were, however, quite similar to those of plots one and three at blossoming time and from this standpoint, we might expect these plants to blossom. In this case, it appears that response of the plants cannot be so readily associated with their relative proportions of carbohydrates and nitrogen.

Summary

1. The amount of continuous light or the relative length of day influenced the time at which blossoms were produced on different horticultural plants.
2. The Biloxi soy bean blossomed much sooner with a short day. The Ruby King pepper, although not affected so strikingly, still proved to blossom and mature its fruits sooner with a short day. Lettuce and radishes, however, blossomed much sooner under the influence of a long day.
3. When plants were subjected intermittently to light and darkness, as were the broken day plants, blossoming was greatly

delayed although the total amount of light received was about the same as that received by the short day plants.

4. Electric light at night, in addition to the normal daylight greatly delayed blossoming in soy beans and peppers, but hastened blossoming in the case of lettuce. Its influence was not so marked with radishes. Intensity of light, within the limits used, did not seem to influence the time of blossoming, although the height and color of plants were influenced.
5. Lack of nitrates in the nutrient solution delayed blossoming of the peppers decidedly in spite of the length of day to which they were subjected. The "low nitrate" series with radishes and lettuce, except the lettuce in the electric light plot, had not blossomed when these experiments were concluded. However, the addition of nutrient solutions, which varied in their nitrate content, did not influence the time of blossoming in soy beans exposed to the same length of day. This can probably be explained by the fact that soy beans are leguminous plants.
6. Definite conclusions are not attempted at this time concerning the correlation of length of day, time of blossoming, and chemical composition of plants. The following paragraphs simply state the conditions found to date.
7. The analyses of soy beans completed to date showed that the short day, twelve hour, plants had at blossoming time a comparatively high percentage of total sugars, and that the percentage of starch was quite high when conpared to the other plots, which had not blossomed. The percentage of carbohydrates was also higher, but the polysaccharides other than starch were slightly lower. The percentage of total nitrogen was less than in the normal day and broken day plants.
8. The normal day plants at blossoming time (86 days) had about the same composition, in comparison to the other plots, that the short day plants had at 33 days when they were blossoming. Thus as in the case of the short day plant, the starches, sugars and carbohydrates were relatively high as compared to the percentage of nitrogen.
9. The broken day plant (plot four) blossomed in 95 days, but did not set. These plants continued to increase in length. Analysis showed that in these plants the percentage of sugar was rather low and that the percentage of starch was very low. The percentages of carbohydrates and total polysaccharides were also lower in these plants than those in any of the other plots. The percentage of soluble nitrogen was quite low, while that of insoluble nitrogen was higher than in any of the other plots at this time. In this group the percentages of sugars and starch were thus relatively low when compared to the percentage of nitrogen.
10. The electric light plants had not blossomed when the experiment was concluded (160 days). They were still increasing in length and had large, dark green foliage. At 105 days, although the percentages of sugar and starch were quite high, still they were

not as great (especially the starch) as were the percentages in the short and normal day plants. The percentages of polysaccharides and carbohydrates were slightly lower also as was the percentage of total nitrogen. Much of the soluble carbohydrates was probably used in extension growth. The proportions of starch and total carbohydrates to nitrogen were, however, quite similar to those of the short day and normal day plants at blossoming time. In this case, then, it appears that the response of the plants grown in 24 hours of light, cannot be so readily associated with their relative proportions of carbohydrates and nitrogen as indicated by mathematical ratios. However, since these plants never blossomed, it is impossible at this time to draw conclusions as to the chemical factors necessary for blossoming in this particular plot.

11. These results suggest that the different responses obtained when the plants were subjected to different lengths of day, might be caused by modifying their nutritional conditions.

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Organizing the College Program

By J. C. Blair

THE papers and reports presented here this afternoon relate to the present position and the future of horticultural instruction and investigation in the agricultural colleges and experiment stations. They are the outcome in part of a paper given last year, which in a

somewhat general way dealt with the ever important question of the improvement of college teaching, of research, and of extension work in horticulture.

The programs of colleges must be continuous with life after graduation. The success or failure of the graduate depends greatly on whether the curriculum has been determined with reference to its utility after commencement.

The organization of subjects in most of our agricultural colleges varies from rigidly fixed curricula to almost a free election system. Experience with the free election system raises the question whether these interests are sufficiently developed or sufficiently defined in the minds of the undergraduates to permit a wise choice. Only a comparatively small proportion of students in our colleges really have a clear purpose in mind when they enter, or a knowledge of the best preparatory training for their chosen life work to enable them to choose wisely their educational program. Free election places the responsibility on the student for determining the educational policy. Are the students qualified to do this? What are to be the aims? Are the motives that guide students the ones best calculated to prepare them for their life work? How are the advantages of the free election system to be harmonized with wise curriculum building? How shall the objectives be determined? And how shall the work be organized to accomplish these objectives? These are a few questions that are worthy of, and requiring, careful and exacting thought and procedure.

In the organization of curricula for effective horticultural education, the question of the discovery and application of proper aims is being pushed to the foreground by the students who enter the institutions for higher education. It seems to me, therefore, that, unless the subjects of curricula are selected, organized, and related according to well-defined principles, the whole process will fall far short of the accomplishment intended, or rightfully expected by the public. Any curriculum, and more especially that in horticulture, must be determined carefully and thoroughly with reference to its utility after the student leaves college. The aims should be determined with respect to social purposes, and the subjects organized for the effective accomplishment of these aims. This should be the first obligation of any agricultural institution.

First, we should determine the objectives, then, a study will need to be made of the situations to be met within the divisions of the field. The organization of curricula should be determined which will best prepare students to meet the duties in that particular field. The content and organization of subject courses of instruction should be determined as well as the methods of teaching most appropriate to these courses. Successful instruction demands that there shall be not only proper content and organization of the subject matter, but also a method of teaching that will be the one best suited to the particular subject and to the abilities of the students taking the course.

The presentation of a subject is just as important as the subject matter. Perhaps the main object of a four-year course is to develop

leadership rather than artisans, remembering, of course, that a leader must know his field thoroughly. However, there is needed a sure method of determining the real educational progress of the individual student. Has he obtained the technical and intellectual growth which should be reasonably expected? Do we know just what should be expected? How can we measure the results achieved? It is clear, I think, that a normal standard can be derived only through years of study.

Much emphasis has been placed upon laboratory work in the curricula of higher educational institutions. In a thorough course of instruction it is looked upon as indispensable, more especially in such science courses as botany, chemistry, genetics, physics, as well as in applied science courses as pomology, agronomy, vegetable gardening, dairying, et cetera. Considering the attention and amount of time devoted to laboratory work in our agricultural colleges it is important that we understand and appreciate the aims and purposes of laboratory work to the fullest extent. There are certain purposes which properly conducted laboratory work fulfill more aptly than any other method of instruction. Laboratory work will teach through the eye as well as the ear. It benefits by giving the student a study period requiring concentration, accurate observation, logical reasoning, and careful manipulation. Likewise, it develops an inquisitive mind, making investigators, more or less, of all students, as well as teaching the principles underlying successful practice. We may say that the chief purpose of laboratory work should be the stimulation of interest and the enthusiasm created in the minds of the students. But, the question arises, are we directing too closely the laboratory work of the student? Are we building their laboratory programs for the students, or are we encouraging them to develop an investigational turn of mind for themselves? Are we teaching the students to arrive at a method of investigation for themselves? How far shall we go?

The science of horticulture has grown out of experimentation. We might call this an age of research. And research in science, pure as well as applied science, has demonstrated its great value by the benefits that can be directly traced to it. Discoveries of untold value to mankind have been made.

The development of modern science probably began in universities and, until comparatively recently, the entire world has been dependent upon the research men of universities and of university trained men for the advancement of scientific knowledge. The importance of this field of endeavor in horticulture has been shown by the number of graduate students who are being trained in research. Many students have been drawn into research work in various stations and because of meagre funds available are subsidized as research assistants. At best such assistants are only temporary and interested primarily in the securing of a degree, while occasionally we find graduate students who are attracted to graduate work through the interest acquired in research. I am in sympathy with the interest which experiment stations have taken in measures

for preparing recruits for horticultural or agricultural investigation. The effect upon the graduate student himself, of an opportunity to serve as a research assistant, can almost universally be considered beneficial. A spirit of research is acquired, they become associated with those who think and live experimentation and research. How much money should go into the establishment of fellowships or scholarships? How far should we go in using graduate students in research work of the station?

The measuring of results is one of the most important factors in any field of endeavor, and in horticultural investigation, or horticultural extension work, it is extremely difficult to find a satisfactory basis for measurement. We may have a general idea of the value of what has been done, but the very character of the work, especially in extension work, does not lend itself to ordinary methods of measurement.

Extension must not mean, or be thought of, only in terms of production or marketing, but it also should mean better agricultural communities and better homes and better farm life. The service would be fulfilling its mission if every farm could be reached so far as distribution of effort is concerned. This, however, is impossible, and this contact would not necessarily give a true measure of accomplishments. Every farmer, however, who is led to put into practice the improved methods introduced by the horticultural extension service is being definitely reached and helped.

Nor can we measure results by demonstrations given, since there are vast differences in the character and value of various demonstrations. We can, however, maintain complete and more or less accurate records of our extension activities throughout the year and in this way attempt a measurement of results. In this way we can find out just what is being done in each county during the space of a year, what is needed by that county, and can use these records in listing farm contacts in the immediate future. These records can then be compared to the production of that locality.

In all horticultural service, whether it be of an instructional nature, research, or extension work, we cannot fail to recognize, or realize, or in any way neglect the fact that in the last analysis we are dependent absolutely upon the mental productivity of men, and men alone. And, in consequence, we must provide adequately for a continuous supply of well-trained workers in horticulture. It is up to us to see that the students of horticulture are given adequate training in college to make of them experts in this field of endeavor. It is our business to encourage research workers in horticulture. I would not be understood as advocating that the function of the college is merely to turn out men skilled in a certain line of work. It is our duty to do more than this. Properly organized curricula will give clear understanding of principles and laws, the forces and elements underlying the skill, and also will there be a wide responsibility felt. Broad versatile culture must be harmonized with the specific tasks, and one must not be allowed to evershadow the other.

The Content of Horticultural Courses for the General Agricultural Student

By V. R. Gardner, *Michigan Agricultural College, East Lansing, Mich.*

THE question of how much work in horticulture should be required of all students in agriculture, and then the question as to the nature of the subject matter to include in these required courses, have been a continual puzzle to horticultural departments and administrative officers. That there exists no great unanimity of opinion is evidenced by the fact that today the amount of work in horticulture actually required in institutions of recognized standing varies from nothing at all to 10 credit hours. Some of those departments now requiring the most work believe that enough time is not allowed; some of those requiring the least believe that the time they now have is ample. As a matter of fact, both groups of institutions have been turning out men of whom they have no reason to be ashamed, men who in after life are able to fill creditably places of responsibility. It would seem that this fact alone indicates that there is nothing essentially vicious or ruinous in requiring all agricultural students to take 10 or 12 credit hours in horticulture; nor on the other hand, is there anything which makes absolutely imperitive the requiring of a single credit hour. It would seem to me that the question is not one of deciding which of these two extremes is right; nor is it one of determining the average for a large group of institutions and then arbitrarily assuming that that average is best. At least an approximate answer can be obtained by going back to a few generally accepted principles and then seeing how they apply to the question in hand.

It will be agreed that the real purpose of any education, including an agricultural education, is *to train the mind to think clearly*, to develop it so that the individual is able to meet the problems and issues of life and work out their solution in an intelligent fashion and with the least waste effort. At the same time it should enable him to establish contact with and appreciate the work of others, as expressed in literature, art, music, science, etc. Courses in pure science and in liberal arts subjects are essential to the last object, and not without importance to the first. Courses in applied science, in particular, contribute toward the training in ability to meet and solve every day problems.

What shall the applied sciences be? Agricultural colleges have been established and developed on the assumption that for those who expect to have much to do with agriculture, applied science means agricultural science. About this there can be no great difference of opinion, though perhaps there is room for considerable discussion as to what shall constitute the proportion of liberal arts, basic science and agricultural science subjects.

Now we come down to the real question—what place does horticulture have in that minimum of agricultural science that should be required of every agricultural student? At this point two other principles, or facts, should be stated: (1) The majority of our four-year agricultural graduates today do not return to the farm. They fill positions of many different kinds, most of which call for certain qualities of leadership in the agricultural field. (2) The required work in horticulture, if any is to be required, as in other agricultural sciences, should be outlined and presented with this point in view.

Does this four-year agricultural graduate— who teaches agriculture in a high school, who becomes a county agent, a creamery or marketing association manager, the agricultural agent of a railway, who is employed for soil survey work, who takes up agricultural journalism, or who goes back to the farm, have any use for horticultural training? In a broad way horticulture deals with the culture and use of trees, shrubs, vines and herbaceous plants (not including trees grown for timber and cereal and forage plants) and with their products. Certainly some of the plants of one or more of these groups have a place on every farm, in every school yard, along every highway, in connection with every area that can be classed as rural or suburban. Country life with these things left out is country life stripped of some of the most important elements that make it worth while. Such being the case it seems to me that a certain amount of horticultural instruction should be required of every agricultural student. To say that none is really necessary, that any graduate can acquire what he may need after leaving college is like saying that all agricultural students might just as well take liberal arts and basic science courses exclusively, picking up their agricultural science as best they can at a later date. They can, it is true, but as a rule they do not. How much horticulture should be required? Personally I would not wish to say. Much will depend on the ability of the instructor. On his ability to assign certain lessons in text books and then quiz the students? No. On his ability to give the student a new, a different point of view; on his ability actually to awaken and stimulate mental processes, to initiate and develop a train of thought that leads somewhere; on his ability to make the student acquire a view of country life that it is safe to say not one in 100 entering college nor one in 10 leaving college possesses.

What should be the nature of the subject matter presented in a required course, or in the required courses, in horticulture? It would seem to me that the statements that have been made throw some light on this question, or, perhaps more accurately, they throw some shadows on it. Certainly the required course in horticulture should *not* be a course in commercial fruit growing, nor in olericulture nor in plant propagation. Neither should it be a course whose principle object is to advertise the work of the department and attract students into the more advanced elective courses. Neither should it be an elementary, preparatory or introductory course, a prerequisite to, and articulating with, more advanced courses that come later. It should be complete in itself, a finished product, a

course in *amateur* as contrasted with *professional* horticulture. It should be taught as a *cultural* subject and be made to have as much cultural value as a course in genetics, morphology, trigonometry or Spanish. It should be as valuable and attractive to a student in liberal arts, engineering or journalism as it is to the student in agriculture. Amongst other things that it should include is a liberal amount of work in landscape gardening. I use that term intentionally to distinguish between what is really meant and what is often taught when the point of view is that of a separate department of landscape architecture. More than any other branch of horticulture, landscape gardening properly taught can make a contribution to country life and to its appreciation and enjoyment that is worth while. Should instruction in the use and culture of fruit and vegetable plants be included in the required work in horticulture? Yes. It would seem, however, that less attention need be given to how to make a hotbed and how deep and how far apart to sow onion seeds, than to the question of how to get the most out of a garden with the least expenditure of time and money. It would seem that when the culture of fruit trees, shrubs and vines is six or eight-tenths a matter of protecting them from their insect and fungous enemies, more attention should be given to those phases of their culture than to the use of the planting board, or the method of laying out an equilateral triangle orchard, or to pruning. Should the same subject matter be taught in the required courses in horticulture in all institutions?—should the same outlines be used? No. In the prairie states the windbreak and shelter belt are important parts of the horticulture of the country life of the region. If horticultural instruction does not center around them, at least they should form a background for it. These things may be more or less ignored in North Carolina or New England. On the other hand, if the required work in horticulture is taught as a cultural subject the substantial groundwork will be pretty much the same regardless of location. Illustrative material and details will vary from place to place.

Do we have a text book or text books which cover the field, which are satisfactory to use in the required freshman or sophomore courses in horticulture? I do not know of any. Are any departments of horticulture giving their required work in the way that has been suggested? I do not know of any. I must frankly admit that our own approach to it is not very close. These things, however, should not blind us to the fact that there is a real need for careful analysis of the question of what should constitute our required work in horticulture and then a straightforward attempt to work out an answer. I realize that few or none may agree with the point of view I have expressed. I have made no attempt to say precisely what should or should not be taught. I shall have accomplished my purpose if I have been able to challenge attention and to stimulate a careful study of the whole question. It may be questioned if appointing a committee to consider the matter and report at a later meeting would result in any considerable progress. However, if most of us will only come to recognize clearly what the real objectives should

be in our different courses and then apply onrselves to working out a procedure that will fit our conditions the net result will be a considerable improvement.

The Principles that Underly the Selection of Laboratory Work in Horticulture

By S. W. FLETCHER, *Pennsylvania State College, State College, Pa.*

IT IS not practicable to attempt to standardize laboratory work in horticulture as taught at different colleges. The plant materials and equipment that are available, the type of horticulture that is dominant locally, the season at which the course is presented, the prerequisite courses that are offered, and other factors, necessarily will influence the selection. It is practicable, however, to attempt to reach agreement on the principles that should be considered in making the selection.

I shall assume at the outset, that we are in accord on the following statement of academic policy, which is fundamental to a profitable consideration of this subject: that the primary purpose of a college course in horticulture is to train men for leadership in the science of the subject, rather than the art; that it has a professional rather than a vocational objective.

If this is a fair statement of our educational ideals, then it follows that the purpose of laboratory work in horticulture is more to train the mind than the hand. It is concerned more with principles than with details. It definitely recognizes its own limitations, chief of which is the fact that it should not be expected to serve as the equivalent of commercial experience to those who plan to enter the commercial field. In short it is a means of education, rather than a means of acquiring skill in handicraft.

Having this point of view, we may now proceed to a more critical examination of the purposes of laboratory work, with the understanding that this term includes field work, or the practicum, as well as indoor studies and practice. These purposes, as I see them, are three and they are here arranged in the order of their relative importance as an aid to effective teaching:

1. To arouse interest in the subject.
2. To illustrate principles that have been discussed in the class-room.
3. To acquaint the student with certain of the more important horticultural operations.

Taking up these purposes for individual scrutiny, the first and paramount purpose—to arouse interest—needs little justification. No instructor is effective, and no student is progressing, who is without enthusiasm for his subject. It is the spark that fires both

to action and accomplishment. It is difficult, if not impossible, to generate enthusiasm for horticulture from books; the student must feel the soil and handle the plant. This is especially true at those colleges which draw a large proportion of their agricultural students from towns and cities, as at Penn State. A well considered series of practicums does more to arouse interest and stimulate ambition than the most brilliant class-room efforts of the most gifted professor. A class without interest is dead, though every student in it may achieve three credits toward graduation.

We are urged to teach principles, rather than details of practice, and this is good pedagogy. But principles are generalizations. They may leave the student with a vague and indefinite conception of the subject unless the principles are translated into the concrete by means of illustrations. Twenty-five years ago, when I began to teach horticulture, my practicums in orchard pruning were directed chiefly toward the objective, "How to prune." I told the student what limbs to cut off on each tree to which he was assigned. I tried to impress upon him my personal methods of pruning. It was a practicum in handicraft, by the rule-of-thumb method handed down by generations of English gardeners bred under the apprentice system. Now I endeavor to teach not so much how to prune certain trees, as to illustrate the principles of pruning, such as the purposes of frame-work training; the comparative effect of heavy and light pruning on the growth of young trees; the fruiting area of a particular tree and the problem in pruning it presents in relation to size of fruit, color of fruit and possible necessity for thinning the fruit. These and similar problems, furnish an infinitely more profitable use of the student's time than merely to prune certain trees.

The inter-dependence of class work and laboratory work should not be disregarded. The same man should teach both, if possible. When the class is large the tendency is for the professor to conduct the class work and assign an instructor to handle the several practicum sections. This may be the most expedient method, but it certainly is not the most effective method.

We come now to that purpose of laboratory work which usually is foremost in the minds of the student and the general public, but last in the estimation of the instructor—to acquaint the student with the methods of performing certain of the more important operations. Manifestly this can be only the briefest of introductions and not a satisfying experience. Most college courses in fruit-growing for example, have but one two-hour practicum a week for 18 weeks. At Penn State we have, in addition, a supplemental practicum course in which one-half day a week is devoted to field work. Then there is the summer practicum of six weeks taken at the college between the junior and senior year, as reported in the 1923 proceedings of this Society. But even this rather exceptional opportunity for practice at the College is wholly inadequate as a preparation for commercial work. It serves one useful purpose, however; it opens up the field to the student so that he begins to surmise how little he really knows of the art. If he hopes to qualify for success in commercial work

he must get the prerequisite experience in commercial establishments, not at the college.

By way of illustrating the application of these three principles to a specific course, I list below the practicums now given in Penn State Hort. 2, Fruit Growing, together with some of the points which we seek to bring out in each practicum. This is an introductory three-credit course offered in the first semester. The practicum subjects are not arranged in the order in which they are discussed in the class room, but in the order in which they are most likely to be seasonable at State College.

1. General Inspection Trip to the College Orchards. Study of different types of cover crops, particularly the relative amount of organic matter produced.

2. Peach Picking. Size and color as affected by degree of ripeness, amount of pruning and thinning; organization of picking force.

3. Peach Grading and Packing. Standard grades, relation of size to sale value, types of packages, packing house organization and equipment.

4. Apple Picking. Relation of pruning, thinning and time of picking to size and color; comparison of results of spraying treatments as evidenced on picked fruit; harvesting equipment and organization.

5. Apple Grading and Packing. Standard grades, types of sizing machines, packing house organization, barrel packing.

6. Orchard Sites. A critical comparison of three representative sites, with the aid of a score card.

7. Laying out and Planting the Orchard. A comparison of methods of laying out the orchard on different sites; factors which affect the method of preparing the trees for planting; planting methods.

8. Spraying and Dusting. Comparison of Spraying and dusting as to (a) time necessary to cover an equal number of trees; (b) amount of materials used per tree; (c) relative thoroughness of covering; (d) comparison of spray guns and nozzles.

9. Bud and Branch Studies. The relative number and position of leaf buds and fruit buds; the relative annual growth of different branches and spurs, with possible explanations; the evidences of crop production.

10. Pruning Young Trees. Comparative effect of heavy and light pruning; principles of frame work training; relation of varietal habit of growth to shape of head.

11. Pruning Bearing Trees. An examination of the fruiting area of representative trees; relation of pruning to size and color of fruit and to fruit bud production; relation between amount of annual growth and crop production; healing of wounds as affected by their size and position.

12. Preparation of Sprays. Lime-sulphur concentrate, self-boiled lime-sulphur, dry mix.

13. Preparation of Sprays. Bordeaux, engine oil emulsion, nicotine and arsenate of lead sprays. Comparison of relative cost per gallon.
14. Descriptions of varieties, comparison of types.
15. Identifying and judging apples.
16. Box, basket and hamper packing of apples.
17. Storage, principles of construction, ventilation and management of common storage houses; study of cellar temperature and humidity records; comparison of storage packages.
18. Propagation. A review of problems in budding, grafting and nursery practice.

The practicums in this course are introductory to the more detailed laboratory work on these subjects given in the pomology courses which follow, including Hort. 5, Systematic Pomology, which is devoted to a critical study of varieties, fruit judging and the botany of cultivated fruits; Hort. 32, Pomology Practicum, in which attention is given to pruning, spraying, harvesting and marketing, with special problems in management; and Hort. 17, The Summer Practicum. It is probable that no other college would find it practicable to adopt, without change, this list of practicums that has been found most useful at Penn State; the point of view in conducting the practicum is far more important than the specific subjects included.

Outline of Course in Freshman Horticulture.

By A. S. Colby, *University of Illinois, Urbana, Ill.*

HORTICULTURE is said to be an applied science. Courses in horticulture should then be outlined and directed by teachers who have both a training in the fundamental sciences underlying horticulture, and a practical experience in the art as well as enough courses in education to enable them to teach according to correct pedagogical principles.

A freshman course in horticulture is of enough importance to require the services of a mature instructor with at least a bachelor's degree. If the instructor does not have a degree beyond his B.S. he should at least be doing graduate work. He should preferably have a doctor's degree, probably in botany. He should carry on some definite experimental or research work and get out over the state occasionally on extension work. Contact with the growers is absolutely essential to the successful teacher in that he can see from actual experience how the principles taught in the class room are working out in practice. A genuine interest in and a love for the work is essential on the part of the instructor. This enthusiasm even goes outside the class room and laboratory in helping the freshman

horticultural student to find himself in the student horticultural organization, and in helping to arrange extra curricula activities such as exhibits for open house, apple judging contests, etc.

At the University of Illinois, courses in fruit growing and vegetable growing are required of all general agricultural freshmen in the general curriculum of the College of Agriculture. Unless the student is to specialize in some phase of horticulture later on in his college career, the above courses include all the work he must take except a course in rural improvement. The latter is a study of ornamental gardening principles and practices, especially from the standpoint of the general agriculturist.

The aim of the courses is to teach the freshman boy and girl enough about the fundamental practices of horticulture so that he or she will be able to carry them on intelligently. To a certain extent they are "appreciation" courses also. They help the student to find himself with reference to the line of agricultural work in which he is most interested, and in which he will wish to specialize later on in the college curriculum.

The student should be taught the "why" as well as the "how." Where the text book used is primarily a manual of practice, as it is at Illinoise, the information as to why the operation is carried on in a certain way should come from the instructor sometimes in introducing the particular laboratory exercise in question, and again while the work is being done.

Other courses required concurrently with horticulture in the freshman year at Illinois include the sciences of chemistry, entomology, and botany. These are given wholly outside the College of Agriculture, being offered in the College of Liberal Arts and Sciences. We are fortunate in having close co-operation between the various departments in that College and our own department. The courses in entomology and botany, for example, are given with special reference to the needs of the agricultural student.

The recitations are primarily quizzes on assigned chapters in a text book. The lecture method has not worked out in a satisfactory manner for freshmen. I have noticed that the best time and place for a lecture, short and to the point, however, is in the midst of a recitation, when the instructor can from his experience in the particular subject being discussed, bring out one or two facts new to the students, which have especial bearing on the matter at hand. The students are ready for such new material just at that time and it will stick better.

The laboratory work is primarily to get the student to think and act intelligently and to record accurately what he sees and does. The exercises are written up carefully and graded on a basis of work done as well as neatness in record. Conclusions to each laboratory exercise are a necessary part of the write-up. As far as possible the laboratory work is done concurrently with the study of the same subject in the text.

We try to have each student do enough work in each particular laboratory exercise to be able to repeat the operation later on with

the help of his laboratory notes. Considerable equipment is kept on hand including machinery, tools and supplies for the use of each student. Over 20 acres are devoted to the growing of trees and plants which the freshmen help to lay off, plant, prune, cultivate, and aid in insect and disease control. Because of this method, many of the students, especially those specializing later in pomology, are able to follow with interest and value the progress of the plants they themselves set out and cared for as freshmen.

Our course in pomology is given the first semester of the collegiate year with the work in vegetable growing the second semester. This arrangement is the best from the standpoint of the seasonable value of the majority of laboratory operations carried on. In many respects, however, courses in horticulture can be given to the very best advantage in the summer when the student can see the results of many of the earlier operations carried on in the laboratory exercises and understand better the problems which come up for solution in the orchard and garden during the growing and ripening season.

Outline of Course in Pomology. (Horticulture 1A) A Required Course in the Freshman Year in the General Curriculum in Agriculture, University of Illinois.
(Two credit hours)

Recitations

1. General Considerations
   The value of fruits as foods; their place in agriculture; objects and scope of the course.
2. Where to Plant the Orchard; locality and site.
3. What to Grow
   Kinds and Varieties; how to choose them.
4. The Plan of the Fruit Plantation; different arrangements; square, hexagonal, etc.
5. Preparing the Land for Planting.
6. Obtaining the Plants
   How plants are propagated. Home vs. nursery propagation, How and when to order plants.
7. Transplanting
   Definition and objects.
8. Soil Management
   Introductory discussion.
   The fertility factor.
   Intercrops, green manures and cover crops.
   Implements; power; seasonal operations.
9. Pruning: Definition and Objects
   Principles underlying pruning of the common orchard fruits.

10. Fruit Protection
    Insect pests.
        Classification as to means of control.
    Diseases
        Classification and descriptions of the most serious.
    Insecticides and fungicides: general considerations; working out a spray schedule for Illinois.
    Application of insecticides and fungicides: use of sprayers; dusters.
    Miscellaneous pests with methods of control.
    Climatic conditions.
11. Saving the Product
    Harvesting and storing orchard fruits.
    Fruit products.
12. Small Fruits and Grapes
    Planning and establishment of the plantation: kinds and varieties to grow: subsequent care of the plantation: insects and diseases: harvesting, storing, marketing.

Laboratory Exercises

1. Observations on Fruits and Vegetables in Champaign Markets.
2. A Study of Sites for Fruit Gardens: Choosing sites for Particular kinds of fruit.
3. Practice in Staking out a Fruit Garden: Demonstrating the Best Arrangements to Use.
4. An Examination of Fruit Packages and Sorting and Packing Apples Using the Illinois Grades.
5. Control of Peach Tree Borers: The Old and the New Ways.
6. Making Grafting Wax and the Operation of Cleft Grafting of Apples.
7. Planting Fruit Trees (where they are to remain).
8. A Study of the Fruiting Habits of the Common Orchard and Small fruits. (Drawings from life required.)
9. A Study of Pruning Tools: Pruning newly transplanted apple and pear trees.
10. Pruning Apple and Pear Trees just coming into bearing.
11. Pruning Mature Apple and Pear Trees.
12. Pruning Young Peach Trees.
13. Pruning Bearing Peach Trees.
14. Pruning Young Cherry Trees
15. Pruning Bearing Cherry Trees.
16. Pruning Grapes, Bush Fruits, and Brambles.
17. Observational Studies of the most Important Fruit Insects.
18. Observational Studies of the most Important Fruit Diseases.
19. Making Bordeaux Lead Arsenate Mixture and Study of the Hand Spray Pump.

20. Making Oil Emulsion and Study of the Power Sprayer.
21. Preparation of Lime Sulfur and Self Boiled Lime and Sulfur.
22. Making up Dusts and a Study of Dusting Machinery.

HORTICULTURE 1B

ELEMENTS OF HORTICULTURE—VEGETABLE GARDENING.

(Two credit hours.)

I. Outline of Quiz Work.

1. Introductory discussion.
   - What is a vegetable?
   - Scope of the course.
   - How the work will be conducted.
   - Types of vegetable growing.
     - Market gardening.
     - Truck farming.
     - Growing vegetables for the cannery.
     - Home vegetable gardening.
2. Soil and location.
   - Soil for home gardens.
   - Advantages of sandy soil for early market gardens.
   - Clay soils.
     - Advantages.
     - Care in working.
     - How to improve.
   - Ideal location for a garden.
3. Hotbeds and coldframes.
   - Construction of manure hotbeds.
   - Construction of fire hotbeds.
   - Constuction of coldframes.
   - Care of plants in hotbeds and coldframes.
4. Factors influencing the quality of vegetables.
   - Freshness.
   - Maturity.
   - Temperature.
   - Moisture.
   - Variety.
5. The Seed Supply.
   - Home production of seed vs. purchase of seed.
   - Factors essential to production of good seed.
   - Cleaning and curing seeds.
   - Vitality of seeds.
6. The plant food supply.
   - Animal manures.
   - Green manures.
   - Commercial fertilizers.
   - Time and method of application.
   - Quantities of manure and fertilizer to use.

7. The moisture supply.
   Importance of moisture in vegetable production.
   Sources of water supply.
   Irrigation.
   Conservation of moisture.

8. The temperature factor.
   Native habitat of different vegetables.
   Cool season crops.
   Warm season crops.
   Adjustment of planting dates to meet temperature requirements.

9. Transplanting.
   Reasons for transplanting.
   Economic questions involved.
   Character of plants desired.
   Protection of plants during and following transplanting.
   Methods of transplanting.

10. Preparation of soil for planting.
    Advantages of fall plowing.
    How to determine when the soil is in workable condition.
    Treatment of areas reserved for late planting.
    Preparation of soil for seed boxes.

11. The planting of seeds.
    Conditions essential to germination.
    Depth of planting.
    Distance of planting.
    Thickness of seeding.
    Methods of sowing seed.

12. Controlling insects and diseases that attack vegetables.
    Mechanical means of controlling insects.
    Trap crops, poison baits and repellents.
    Treatment of seed for insect and disease control.
    Fumigation.
    Spraying.
    Formulas for spray mixtures.
    Dusting.

13. Early short season crops.
    Leaf lettuce.
    Garden cress.
    Corn salad.
    Spinach.
    Mustard.
    Radishes.
    Turnips.
    Kohlrabi.
    Peas.

14. Early transplanted crops.
    Head lettuce.
    Cos lettuce.
    Early cabbage.
    Early cauliflower.

15. Late cabbage and allied crops.
    Late cabbage.
    Late cauliflower.
    Broccoli.
    Brussels sprouts.

16. Celery.
    Soil and moisture requirements.
    Growing the plants.
    Transplanting.
    Blanching.
    The "New Celery Culture."
    Celeriac.

17. Heat resisting root crops.
    Beets.
    Carrots.
    Parsnips.
    Salsify.
    Horse-radish.

18. Greens and salads that endure heat.
    Swiss chard.
    Kale.
    Collards.
    New Zealand spinach.
    Parsley.
    Upland cress.
    Endive.

19. Onions.
    Temperature and moisture requirements.
    Preparation of land for onions.
    Sowing onion seed.
    Tillage.
    Weeding and thinning.
    Harvesting.
    Curing.
    Growing onions by the transplanting method.
    Growing ripe onions from sets.
    Growing onion sets.
    Green bunch onions.

20. Other plants of the onion group.
    Leeks.
    Garlic.
    Shallots.
    Chives.

21. Potatoes.
    - Early and late potato producing states.
    - Soil.
    - Planting.
    - Tillage.
    - "Straw Potatoes."
    - Control of insects and diseases.

22. Perennial crops.
    - Asparagus.
    - Rhubarb.
    - Globe Artichoke.
    - Sea kale.

23. Beans.
    - String beans.
    - Lima beans.
    - Dry beans.

24. Sweet corn and crops requiring similar culture.
    - Sweet corn.
    - Popcorn.
    - Okra.

25. Muskmelons.
    - Soil and location.
    - Planting.
    - Thinning the plants.
    - The transplanting method.
    - Cultivation.
    - Insects and diseases.

26. Other vine crops.
    - Watermelons.
    - Citrons.
    - Cucumbers.
    - Gherkins.
    - Pumpkins.
    - Squashes.

27. Tomatoes.
    - Growing the plants.
    - Transplanting.
    - Cultivation.
    - Staking.
    - Picking.
    - Diseases.

28. Eggplant.
    - Growing the plants.
    - Transplanting.
    - Cultural requirements.
    - Protection from insects.

29. Peppers.
    - Growing the plants.
    - Transplanting.
    - Tillage.
    - Types.

30. Sweet potatoes.
    - Temperature and soil requirement.
    - Propagation.
    - Planting.
    - Cultivation.
    - Harvesting.
    - Types.

31. Systems of intensive cropping.
    - Companion cropping.
    - Succession cropping.
    - Combination of the two systems.
    - Relative merits of the different systems.

32. The home vegetable garden.
    - The farmer's garden.
    - The village or suburban garden.
    - The city garden.
    - Varieties of vegetables for the home garden.
    - Quantities of seed to buy.

33. Harvesting and marketing.
    - Time of harvesting.
    - Packing sheds.
    - Washing and bunching.
    - Grading.
    - Packing.
    - Selling the crop.

34. Storage of vegetables.
    - Conditions essential to successful storage.
    - Vegetable storage houses.
    - Storage in small quantities for home use.

II. Laboratory Exercises.

1. Making hotbeds.
2. Preparing soil for seed flats and sowing of seed.
3. Planning a farm home vegetable garden.
4. Study of vegetable seedlings.
5. Shifting cabbage and lettuce seedlings from flats to hotbeds. Sowing tomato seed.
6. Detailed study of farm home garden plan.
7. Shifting tomato seedlings from flat to hotbed. Treatment for seed potatoes for scab.
8. First planting in farm home garden.

9. Second planting in farm home garden.
   Transplanting of cabbage.
10. Shifting tomatoes in hotbeds.
    Study and operation of garden seed drills.
11. Study and operation of wheel hoes and other garden tillage tools.
12. Third planting in farm home garden.
13. Cultivation and weeding of early plantings.
14. Fourth planting in farm home garden.
    Transplanting tomatoes.
15. Weeding and thinning of early crops.

Outline for Sophomore Horticultural Courses

By L. GREENE, *Purdue University, Lafayette, Ind.*

THE TWO horticultural courses described in this paper are, with modifications, those now required of all agricultural sophomores at Purdue University. The plan of the curriculum in the Purdue School of Agriculture provides during the freshman and sophomore years, introductory courses related to each of the agricultural industries.

The aim is to give the student a broad view of agriculture and to acquaint him with the practices and opportunities in each industry that he may more intelligently select the optional group of subjects he is to follow during his junior and senior years.

Three courses in Animal Husbandry, three in Agronomy, two in Farm Mechanics, two in Horticulture and one each in Dairying, Farm Management and Poultry, are required during these first two years in addition to such subjects as, English, Mathematics, Chemistry, Physics, etc. No electives are provided for the first two years and few are allowed in the junior and senior years.

The horticultural courses described are comparable with beginning courses in other institutions. Each is one semester in length, since much detail could not be given where less time is alloted.

Many of our students are not in the least familiar with either the science or practice of horticulture thus necessitating careful training in both.

The aim is to train the student in the art, or practical phases, of horticultural pursuits that he may be best able to make use of them on the farm, as a vocational teacher, as a county agent, or in other activities where a general knowledge of practice will be helpful. The entire field can not be covered and certain phases are covered more or less thoroughly with a basis for future study emphasized.

While a general and practical knowledge of horticulture is the aim, scientific principles are not lost sight of. Our aim is to apply the

underlying scientific principles upon which each operation is based. An attempt is made to develop a thorough knowledge of theories related to practice as well as an intimate knowledge of these operations. We hope to develop men capable of leading along new lines rather than to develop skilled artizans or practitioners without theoretical knowledge.

If the value of science to horticultural pursuits is to be emphasized, the instructor should have a sympathetic attitude toward, and better still, a comprehensive knowledge of, the sciences upon which horticulture is based.

The content of these courses is largely a result of 10 years experience with general agricultural students on the part of Professor W. E. Lommel of the Purdue horticultural staff. The work in vegetable gardening has been modified and strengthened during the last two years by Professor H. D. Brown who has administered that part of the work. An outline of each course follows.

The Principles of Fruit Growing

This is a two lecture and a one two-hour laboratory course for which 2⅔ credits are given.

Objects: First—To develop in the student's mind an understanding and appreciation of what is meant by fruit of good quality and to help him to realize the need for such fruit in the home.

Second—To teach the principles of growing various fruits so as to enable the student to set and care for enough plants to supply his family with a variety of fruits, and to impress upon him the necessity for good care of these plants.

Third—To give enough technical training, especially in apple growing, so that with additional self-directed study and practice the student may successfully manage a small commercial orchard containing various kinds of fruit.

Fourth—To bring to the attention of the student the application of scientific principles to the work being studied. An attempt is made to apply at least one scientific principle to each lesson using such subjects as "winter injury," "fruit bud formation," "transpiration," etc. These are explained with scientific applications using terms and problems adapted to students of this grade.

Most of the recitation assignments are from the text by Sears, entitled "Productive Orcharding." Corrections and additions for Indiana conditions are made. As this text confines itself almost entirely to apple culture other assignments are given, particularly in Purdue bulletins and circulars, covering various other fruits. Three lectures on plant propagation are included. The status of the horticultural industries is pointed out and the activities of leaders in the field are called to the students' attention.

As no other opportunity is offered for acquainting the student with landscape architecture, illustrated lectures covering the principles involved are included. Emphasis is given to the ideal that a country home deserves beautification and good care.

Laboratory Work

1. *Selecting Orchard Sites*—Score cards are used. Three sites are visited, scored and placed by each student. Reasons are given for the placing.

2. *Study of Spray Materials*—Studies of liquid lime sulfur, especially the use of the dilution table, and of lead arsenate, are made in the laboratory.

3. *Preparation of Concentrated Lime Sulfur and Self-Boiled Lime Sulfur*—Two men work together. Each pair prepares one gallon of liquid lime sulfur.

4, 5, and 6. *Apple Pruning and Peach Pruning*—Each man is equipped with a set of tools and works for three periods at practical pruning. Most of the work is in mature trees.

7. *Preparing Bordeaux Mixture*—Men work in pairs. Each pair makes Bordeaux and studies its properties in the laboratory.

8. (a) *Planting and Pruning Nursery Trees.*
(b) *Inspection of Purdue Pruning and Cover Crop Experimental Plots.*

These two are combined because the planting and pruning of a nursery tree does not require very much time; the class is near the plots when planting; and the pruning experiments and pruning of the young tree by the student are closely related as to material.

9. *Dormant or Summer Spray Application*—An application of one of the regular sprays by students. Hand outfits are used in the orchard.

10. *Miscellaneous Spray Materials*—A study of dry lime sulfur, nicotine sulfate, Paris green, oil sprays, and either Pyrox or Bordo-lead, is made in the laboratory.

11. *Mixing Combination Apple Sprays*—Small quantities of the combination sprays used in the Indiana spray schedule for apples, are prepared and studied in the laboratory.

12. *Insect and Disease Injury to Fruits*—The more common pest injuries to fruits are displayed in the laboratory for reference and each student must obtain at least five different injuries to fruits, label each and hand in the collection.

13 and 14. *Apple Judging and Variety Study*—An attempt is made to familiarize the student with a very few of the standard varieties of apples and to teach him how to select a good plate of apples. These periods immediately precede the Purdue Horticultural Show.

15. *Cleft and Whip Grafting*—Individual work by the student in the laboratory.

16. *Planning the Home Fruit Garden*—Each student plans a home fruit garden containing an assortment of tree and small fruits in sufficient quantity to supply the needs of the family.

17. *Barrel Packing of Apples*—Students work in groups of six to 10 owing to lack of materials and equipment.

18. *Apple Orchard Problem*—Sufficient data are given so that in one period each student can figure the cost of caring for a 20 acre apple orchard and the returns which might be expected during an average year.

Sample Laboratory Outline

Mixing Combination Apple Sprays

Exercise No.
Materials:—

Concentrated lime sulfur
Lead arsenate
Nicotine sulfate
Copper sulfate
Hydrated lime

Apparatus:

2-3 quart kettles	1-pint graduate
1-10 inch pan	1-graduated glass cylinder
1-half gallon measure	4-glass cylinders
1-granite spoon	1-hydrometer

Directions:

First study carefully the spray schedule in Purdue Extension Bul. No. 80.

Prepare one-half gallon each of the dormant, pink, calyx, and two-weeks' sprays for apples.

Use 1° Baumé lime sulfur for the fungicide in the pink and calyx sprays, and Bordeaux mixture for the fungicide in the two-weeks' spray. Use nicotine sulfate in the pink spray only.

Test each lime sulfur solution after diluting and before adding other materials. If the solution is not of the desired strength add more water or concentrated lime sulfur as the case may be, until the correct reading is obtained. Be sure that the solutions are thoroughly stirred before testing.

Set aside a cylinder of each spray for observation and label according to the following model.

Dormant Spray

Material: 5°B. lime sulfur
Applied for: Scale insects.
Time of Application: When the trees are dormant.

After a cylinder of each spray has been properly labeled, have them approved by the instructor.

Questions:

1. Give the chief pests controlled by each insecticide and fungicide in each of the four combination sprays, when applied at the time recommended. Use the following as a model.

PINK SPRAY

Materials	*Pest Controlled*
1°B. lime sulfur	Scab
Lead arsenate	Curculio, canker worm
Nicotine	Aphids

2. Why is the amount of paste lead arsenate needed to poison 50 gallons of spray twice that of the powder?

3. Which of the four applications studied is the most important in the control of curculio? Why?

4. Which is the most important in scab control? Why?

5. Which are the most important applications in the control of codling moth? Why?

6. Why is Bordeaux mixture rather than lime sulfur used in the two-weeks' spray?

7. What insects are controlled by nicotine sulfate? How does this material control them?

8. How and when is San Jose scale controlled?

Write a complete report of the work done in laboratory, amounts of materials used, and physical properties of the completed sprays. Include answers to above questions.

FIELD EQUIPMENT

In connection with laboratory work we believe it is as essential that the student have available for study his horticultural plants and equipment as it is for the mechanical engineer to have a machine shop, or the animal husbandryman to have live stock. We are, therefore, attempting to develop orchards and small fruit plantations together with field equipment for their operation.

PRINCIPLES OF VEGETABLE GROWING

This is a two hour recitation course carrying two credits. No laboratory time is available.

Object: First—To give adequate preparation for the study of advanced courses in Vegetable Gardening. These advanced courses lead to specialization in Vegetable Gardening.

Second—To teach the fundamentals involved in the production of quality vegetables. Many vegetables lack quality. This fact is largely responsible for much of the disfavor for certain vegetables. The cultural practices and other essentials necessary for the production of the best quality for home and commercial gardens are discussed. Emphasis is placed upon such crops as are grown commercially in Indiana, especially by the general farmer.

Third—To round out the general education of agricultural students. No matter what line of agriculture is pursued and no matter how restricted the field, there is bound to come a time when a knowledge of related subjects will either directly or indirectly prove beneficial.

Fourth—To provide a fundamental background for county agents and vocational teachers. Various vegetable crops are of considerable importance in many Indiana counties. Since many prospective county agents will be unable to take the more advanced courses in vegetable gardening a special effort is made in this course to point out the principle sections of the state where the various vegetables are grown and to discuss the commercial production of these crops.

Vocational agricultural teachers are frequently called upon for instruction along vegetable lines and especially to lead boys' clubs. Some time is devoted to preparation for these activities.

County agents and vocational teachers frequently need more detailed information than that given in this course. A list of references is attached to each lesson assignment or plan. These references are not a part of the assignment, but are meant for convenience in looking up information later.

The major portion of the work consists of assignments in the text by Professor J. W. Lloyd entitled "Productive Vegetable Gardening."

In order to provide special information concerning Indiana vegetables and in order to supplement the text with certain newly discovered facts, mimeographed sheets, which contain information not given in the text, are handed to the student. Students are held for all information included in these mimeographed pages and text assignments.

Sample Mimeographed Lesson, Horticulture 12
Tomatoes

Lesson 22:

Assignment, Text pp. 244–251.

Over 70,000 acres of tomatoes are grown for the canning factories in Indiana. Over 200,000,000 plants are required to set this acreage. Tomatoes are, therefore, a very important crop in Indiana's diversified farming program.

While it is true that the canning crop must be grown economically, it has been proven that sash grown and transplanted plants can be used profitably. In order to eliminate the expense of transplanting, cost of sash, etc., many factory owners purchase southern grown plants for their growers. Plants for the canning factories are produced in the following ways:

1. Plants started under glass (greenhouse or hotbed) and transplanted to cold frames(either in flats or directly to soil in cold frame) before they are planted in field.
2. Plants started under cold frames covered with glass or other protection such as muslin, cell-o-glass, glass cloth, etc., and then set in field.
3. Plants started in a fertile piece of ground in the open.
4. Plants secured from southern sections.

The tomato is subject to attacks by the three major pests stressed in this course. 1. Nematodes, are frequently found on southern grown plants. (In 1922 over 17,000,000 plants were condemned by

the state entomologist because they were infested with nematodes.) 2. Fussarium is becoming a very serious disease. A great number of resistant strains have been produced. Among the most promising of these strains are Marvel for forcing, and Norton, Norduke and New Century for canning and outside culture. 3. Mosaic is found in most sections of the state. It is carried over winter by the perennial ground cherry and by tomato plants in greenhouses.

In addition to the above pests, the leaf spot is a very troublesome disease.

The Baltimore variety is grown almost exclusively for the canning factory. This year the Indiana Canners Association in cooperation with the Purdue Agricultural Experiment Station produced over 6,200 pounds of tomato seed of the highest possible yielding capacity. The seed was all treated. ($HgCl_2$—1 part to 3000 parts water.)

Problem 1. Estimate the cost per 1000 of growing tomato plants according to method one above (cost of sash $3.00 per sash 3 feet x 6 feet). 2. How many sash would be required to grow plants for the entire Indiana acreage? Figure on 200,000,000 plants and allow 2 inches by 2 inches for the plants in the beds.

Questions:

How many acres of tomatoes are grown for canning in Indiana? How many plants are required to set this acreage? Describe four methods of growing plants for canning factories. What variety of tomato is largely grown? When should tomatoes be transplanted to the field? What are the advantages of staking tomatoes? Describe a tomato plant affected with the following pest: 1. Nematodes, 2. Mosaic, 3. Wilt (fusarium), 4. Leaf spot. How may each of the above pests be controlled? How are tomatoes cultivated? How are tomato plants "hardened off?"

Reference, Purdue Agr. Exp. Station Bulletin 259.

Floriculture

"Lectures" on floricultural pursuits and the forcing house industries are included.

While at present no laboratory time is available we believe that a two hour period would greatly aid in arousing interest in the subject and in demonstrating principle and practice. We also believe that such laboratory practice would prove especially helpful to those who become county agents or vocational teachers.

Shall We Teach Science or Practice or Both?*

By W. H. ALDERMAN, *University Farm, St. Paul, Minn.*

AGRICULTURAL education, as far as agricultural colleges were concerned, was originally founded upon the teaching of the art of agriculture. At that time there was little of science to teach. As long as this condition prevailed the agricultural colleges made slow progress. Eventually it became apparent that the practice of agriculture differed widely in different localities and that there was and could be but little uniformity in the teaching of various colleges when merely the art was taught. The need for a knowledge of the principles underlying practice became apparent. Coincident with the realization of this need came the agricultural experiment stations. Since their organization a mass of scientific material of a teachable nature has been collected and made available for agricultural instructors.

With such scientific material at hand, a new policy became fairly well established 25 years ago or more. This policy called for the teaching of fundamental principles underlying the practice of agriculture and for the teaching and demonstration of methods, but did not attempt the development of artisan skill and dexterity. That is, it was deemed proper to teach a man the methods of grafting and the principles underlying the formation of the graft union, but it was felt to be entirely outside the province of the college to develop skillful and speedy propagators. The principles of pruning might be taught and demonstrated. To train the students to become rapid and skillful pruners was quite another thing. This skill and experience going with it could and should be secured by actual practice away from the college. There have always been more or less outstanding exceptions to this policy, such as training skillful student judging teams, but in the main the more recent educators have stuck to science and fundamentals and have limited the amount of *art* entering into their courses to such as is necessary to develop and illustrate the principles and to demonstrate working methods. Lately the mass of scientific data upon which horticultural science is based, has become so amplified and has been used so extensively in college teaching that the question has arisen, "Are we making our courses in horticulture too scientific for the good of the student?"

Assuming the possibility that horticultural courses *may* be made too scientific and that there *may* be at the present time a real danger arising from that direction, it behooves us to consider carefully how far we may safely go in the introduction of science into our courses and how much of the practice we may safely eliminate. Much will depend upon the class of students concerned. Reflection shows that there are three general classes to be considered, first, the junior

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college or elementary students, second, the upper class or advanced students, and third, graduate students.

Elementary Classes

Most colleges require one or two courses in elementary horticulture to be taken by all students in the college, generally in their freshman or sophomore years. It is in these courses that we need to make our most careful blend of practice and principles, of art and science. A large group of students will take no more horticulture than is given in the required courses, whereas, a second and usually smaller group will be interested in horticulture and will continue their work with advanced subjects. For the first group these elementary courses must contain enough of useful, practical information, to prevent their making ridiculous or serious blunders later on. As one horticulturist rather aptly put it, "The function of the elementary course is to teach the average student enough to prevent him from making a complete fool of himself if he attempts to practice what he is taught." This, of course, means that in these courses there should be considered as thoroughly as possible the most important horticultural practices, but for every practice which is discussed and recommended the student should be shown as completely as available time and his capacity will permit, the fundamental science upon which that particular practice is founded. It is obvious that in an elementary course we must deal with these principles in an elementary manner. It is equally true, however, that in these early courses the mind of the student should be directed by every possible means into scientific channels. It is here that the student will glimpse more involved and difficult questions that can be considered only in more advanced courses and for which adequate scientific preparation is essential. If the instructor does not attempt to develop a scientific attitude of mind on the part of the student, even in the elementary teaching, he is derelict in his duty to the student. While these beginnings of a scientific foundation are being laid, the students must also be given an opportunity to acquire through actual practice a knowledge of the best methods employed in the various horticultural operations. This does not mean the development of technical skill in manipulation, but merely a sufficient amount of knowledge to show him how to proceed. The development of dexterity will come by slow degrees and with practice.

A beginning course in fruit growing will ordinarily contain practical exercises in such operations as pruning, planting, grafting, spraying, etc., but it may also contain, with profit, exercises involving a truly scientific examination of such things as the growth and fruiting habits of various fruits, or the formation of fruit buds. It may include a pot experiment handled by the students and illustrating the working of the carbo-hydrate-nitrogen ratio. The introduction of some scientific experiments into the laboratory program does much to stimulate and hold the interest of the average student.

Possibly the more definite organization of teaching material is the thing most sadly needed in most of our elementary courses. Definite, clear-cut, well outlined laboratory projects are essential. The horticultural teacher is, as a rule, considerably behind the instructor in botany and biology in this organization of material. Too frequently does it happen that the laboratory exercise becomes more of a demonstration by the instructor than it does a practicum for the student.

Advanced Classes

Only students interested in horticulture and specializing more or less in this subject will be found in the more advanced classes. Here a different situation exists than was found with the elementary courses. With most of the students a background of practical information may be assumed to already exist. The occasional student who has had no practical horticultural experience always finds himself badly handicapped and should seek every opportunity to acquire practical experience in a real horticultural enterprise. It is only in this way that he may get a first-hand knowledge of every day details and may acquire the point of view of the practical man. Since this practical knowledge may be assumed in this group of students, they can be taken more and more into a study of advanced problems and led more and more into a probing of original sources of information. It is here that they should begin to apply for themselves scientific principles that have come to them from supporting courses in general science. Horticultural practice and horticultural problems are still the basis of the teaching. The function of the advanced courses lies in the solving of the problems and the determination of the best practice through such science as the student has become capable of using.

Graduate Students

In the graduate school the field becomes more specialized, but the scientific background must be both broadened and intensified. Much of the actual training of horticultural graduate students must rest in the hands of service departments where advanced work in such sciences as biochemistry, plant physiology, cytology, ecology, micro-chemistry, genetics, pathology, entomology, etc., may be pursued. Graduate training has come to be considered a necessary prerequisite to all lines of professional horticulture, teaching, extension and research. Essentially it consists of training the student to marshal in an orderly manner his total scientific and practical knowledge and to focus it on some particular problem in which he is interested. Unquestionably the great bulk of graduate instruction should have to do with science, but it is well for us to remember that science becomes no less scientific when it is applied to practical problems.

Conclusions

Practice and science must be blended in our teaching, but always in such a manner that it may be clearly seen that the practice is based upon the science.

Methods may be taught and demonstrated, but training to skillful proficiency in manipulation is out of the question and must be secured outside of the regular college curriculum.

As the mass of fundamental scientific information increases, it is going to become increasingly difficult to so organize the courses, particularly the elementary courses, that they contain the proper proportion of science and practice. The instructor will not go far wrong, however, if he keeps in mind the fact that modern horticulture is a practical industry operating in a scientific manner and if he makes his scientific teaching as practical as possible and bases his practical teaching firmly upon a foundation of solid science.

What Are We Going To Do with Horticultural Students Who Have Had Training in Horticulture through Vocational Agricultural Courses in High Schools or Colleges?

By J. W. Lloyd, *University of Illinois, Urbana, Ill.*

THE quite general introduction of agricultural teaching in the high schools through the Smith-Hughes Act has added a new problem in the planning of courses in the agricultural colleges. Formerly it was assumed that a freshman came to the agricultural college with no previous contact with technical agricultural training, and the introductory courses were planned accordingly. Now, a college freshman may have had class work in agriculture for two, three or even four years, including home projects as well as text book and laboratory work. The time has come when some recognition of this fact must be made by those in charge of instructional work in the agricultural colleges. The situation is complicated by the fact that only part of the freshmen have had high school work in agriculture, and these have had it in varying amounts. However, those who have had only two years of agriculture in the high school usually have had no horticulture whatever included in that agriculture, except possibly a few exercises added as a sort of appendix to the course in crop production. Only the high schools offering three or four years' work in agriculture are likely to give a course in horticulture that amounts to enough to be considered when planning college horticultural work for high school graduates who have studied agriculture. Fortunately, the better equipped schools are the ones most likely to be giving horticultural instruction.

As a matter of fact, a very large proportion of the high school graduates entering the agricultural colleges will not have had sufficient training in horticulture to warrant making any special provisions in college horticultural courses to meet their needs. The situation in some other departments, in animal husbandry for example, is entirely different; for most high schools devote an entire year to animal husbandry, including extensive practice in judging live stock, often under the instruction of men who have specialized in live stock work in college. On the other hand, relatively few Smith-Hughes high school teachers have majored in horticulture in their undergraduate days. An agricultural student who has had only a little instruction in horticulture in high school needs a thorough introductory course in the subject in college, the same as every college freshman needs a good course in English composition regardless of how much instruction along that line he has had in high school.

In the case of students who have had a full year of instruction in horticulture in a good high school, some adjustments should be made to avoid the necessity of repetition; for an enterprising high school teacher will usually plan a course embodying much of the material used in the introductory course which he took in the same subject when in college. Most of the high school agricultural teachers are young men who have recently been in college, and the agricultural college courses have not been changed much since their graduation. So their high school graduates are likely to encounter nothing very new in some of the introductory courses in college. It is a waste of time for a good student to cover practically the same ground in college as he did in high school.

There are two ways in which this difficulty may be avoided. High school graduates who have had a full year's course in horticulture may be allowed to omit the introductory college course in the subject (which is usually prescribed in a four-year curriculum in general agriculture), and substitute therefor, one of the more advanced courses in horticulture. This is on the assumption that the high school work in horticulture has been sufficiently thorough to enable the student to proceed advantageously with the advanced course. This would be possible only in the case of graduates of the better high schools, where the instruction in horticulture is in charge of a teacher who has had adequate horticultural training. The other way to handle the situation would be to provide a special course in horticulture for students who had previously taken high school horticulture, and allow them to substitute this special course for the regular prescribed course to meet the graduation requirements, or to satisfy the prerequisite for admission to more advanced courses. This special course would be in the nature of a rapid survey of the field of horticulture; it would require less time and carry fewer credits than the regular introductory course. It would need to be handled by an experienced teacher who is fully alive to the needs of this particular group of students. The work should be so much better done than is possible in most high schools, that the students will forget any disappointment that they may have felt in being required to take ad-

ditional work in introductory horticulture. A special course of this sort will be warranted only when students who would be especially benefited by such a course begin to come to the agricultural colleges in sufficient numbers to make classes of reasonable size. Until then the other alternative might well be employed, even though there is always danger of admitting students to advanced courses without sufficient preparation.

There remains the matter of transfer students from other colleges. These should be given credit for what horticultural work they have done, and allowed to enter such courses as they are qualified to take.

Outline of Course in Horticultural Experimentation and Research

By B. S. PICKETT, *Iowa State College, Ames, Iowa.*

A COURSE in horticultural experimentation and research may be useful in preparing men for work in this field by clarifying and defining the scope and boundaries of horticulture, by indicating methods of attack on problems of horticultural investigation, by orientation of students' minds with reference to the relationship of horticulture and agriculture in general and agricultural institutions in particular, by indicating sources of endowment and means of securing a working plant, by criticized practice in preparing plans for conducting experimental work, by a critical study of typical examples of research, by drawing generally on the experience of the teacher through discussion, and by that sharpening of the perception and enlarging of the outlook of the student that goes with a serious pursuit of any advanced course.

A course in horticultural experimentation and research should be elective rather than required. Its length should not exceed five semester hours and excellent work that will be very suggestive to students can be given in three hours. The course should be confined to senior and graduate students and should be protected by prerequisites insuring that it be taken only by students who are promising material for research men.

In a typical three-hour course, two periods per week of one hour each should be devoted to lecture, recitation and discussion, and one period of two to three hours to laboratory work. In an ordinary 18 weeks' semester there will be approximately 30 periods available for lectures, recitations, or discussions, and 15 for laboratory exercises, the other periods being taken up with examinations and contingencies. In a five-hour course there should be three lectures, recitation, or discussion hours and two laboratory periods, per week.

The following is suggested as an outline for a three-hour course:

I. The Field of Horticulture.

II. History of Horticultural Experimentation and Research.
Trace evolution from emperical type of private experiment to highly developed type of fundamental research now prevalent.

III. Endowment of Horticultural Experimentation and Research.
Money necessary in considerable amounts and insured for long periods of time.
(a) Private.
(b) Public.
1. Federal.
2. State.

Securing endowments:
(a) Secure confidence of people.
(b) Work through organizations representing horticulture.
(c) Prepare clear-cut forcible line of argument for funds needed.
(d) Necessary to have faith in projects proposed.
(e) Render continuous service to and keep in close touch with horticultural interests.

IV. Organizing for Horticultural Experimentation and Research.
A. Training and qualifications of research workers for horticultural research.
Men are the most important requisites in organizing for horticultural research.
Requirements for research men in horticulture.
1. Possessed of impartial judgment.
2. Enthusiastic for work—intensely curious possessing missionary spirit.
3. Persistent in following a definite purpose.
4. Well trained.
(a) In fundamentals including underlying sciences.
(b) In the arts of horticulture as in propagation, pruning, greenhouse management, gardening, etc.
5. Experienced:
(a) In general problems of investigation.
(b) In local horticultural needs and practice.
6. Possessed of vision:
(a) Possessed of faith to believe that his own horticultural research will mean something to horticultural industry.
(b) With large outlook for the future.

B. Equipment of plant needed:
1. Land:
(a) Amount.
(b) Character of.
(c) Location.
2. Plants, the chief source of material for horticultural research:
(a) Collections of varieties and species.
(b) Requirements as to number and character in cultural types of experiments.
(c) Arrangement.

3. Buildings:
   (a) Administration.
   (b) Indoor laboratories.
   (c) Greenhouses.
   (d) Storages.
   (e) Packing and receiving sheds.
   (f) Manufacturing laboratories.

4. Miscellaneous:
   (a) Fences.
   (b) Tools.
   (c) Horses, tractors, etc.

C. Departments:

The department a principal unit in college and experiment stations.

Departments built on two theories:

1. The development of a field of work around an able man,
2. The determination of a natural field of work of sufficient importance to call for distinct development.

Horticulture a group of units somewhat easily divided but possessing common bonds of unification.

Two theories of organization within the Department:

1. On the basis of the art, as fruit growing, vegetable gardening, floriculture, and landscape gardening.
2. On the basis of the sciences fundamental to and assisting horticulture, as plant physiology, plant pathology, entomology, genetics and chemistry.

Department organization desirable for:

1. Stability.
2. Convenience in coordinating labor, machinery, power, etc.
3. Strength of concerted action and purpose.

V. Organizing and Laying Out an Experiment or a Piece of Research:

A. The organizing and laying out of an experiment or a piece of research should be based on scientific method, which consists in:

1. Accurate observation, requiring,
   (a) Uniform basic materials.
   (b) Controlled conditions for variable factors,
   (c) Uniform conditions for constant factors.
   (d) Sufficient checks or controls for comparisons,
   (e) Ingenuity in evaluating effects of variable factors as in measuring, weighing, describing colors, flavors, etc.

2. Accurate notation, requiring:
   (a) Permanent records; memory untrustworthy.
   (b) Use of forms.
   (c) Helpful abbreviations.

(d) Dating of all original records.
(e) Photographic records
(f) Filing systems for records.

3. Tabulation and arrangement of data:
   (a) To make records usable.
   (b) Complexity of tabulation dependent on quantity and complexity of notation or record.
   (c) Form of tabulation including graphs, curves, etc.

4. Conclusions:
   (a) Derived from tabulations.
   (b) Interpreted in the light of allied and related investigations.
   (c) To be examined critically by other investigators and by colleagues.

5. Publication:
   (a) Character of write-up dependent on publication and purpose.
   (b) Available places for publication.
      1. Reports of horticultural and botanical societies.
      2. Experiment station bulletins.
      3. Agricultural press.
      4. Books.

B. Choice of subject should depend on:
1. The pressing needs of the industry of horticulture.
2. The adequacy of available equipment and funds.
3. Its conformity to the ideals of good research and experimentation.
4. Its conformity to the stipulations laid down for the use of the funds concerned.
5. The originality of the problem.
6. Personal interest of the experimenter.
7. Training of the experimenter.

C. Outline of procedure:
1. Statement of the objects of the work.
2. Careful description of variable factors of work, as plat treatments, samples, sections, etc.
3. Drawings showing diagramatically or graphically the location and arrangements of the plats, etc.
4. A calendar of work.

Discuss outline with several parties competent to criticize it and make suggestions in order to:
1. Make it as perfect as possible.
2. To protect the experimenter from unfair criticism later.

Note necessity for permanent outline of project concerned:
1. To prevent deviation from plan.
2. To permit continuation of the work by other experimenters if necessary.

D. Estimates of cost:

Estimates of cost may involve:

(a) Salaries and wages.
(b) Rental of land.
(c) Equipment and materials.
(d) Travel.
(e) Administration.
(f) Publication.
(g) Contingencies.

E. Putting the plan into execution:

1. Assembling materials with which to work. Note that task is easy or difficult according to character of problem and available equipment. Consult texts, catalogs of apparatus, engineers, other experimenters.
2. Selecting place for work:

Land secured by:

(a) Gift.
(b) Free use for experimental purposes.
(c) Lease.
(d) Purchase.

Indoor laboratories:

(a) General.
(b) Special.

3. Laying out experiment.

Reducing probable error in field plats:

(a) Size.
(b) Arrangement.
(c) Repetitions.
(d) Controls.
(e) Uniformity in plants, planting, etc.
(f) Regard for time required as in spraying experiments, or experiments involving time factors.

4. Performance of work involved in experiment:

(a) Amount of personal attention required.
(b) Extent of delegation of work permitted.
(c) Success of experiment dependent on scrupulous attention to every detail.

5. Securing Records:

(a) Accurate records must be secured regardless of personal inconvenience.
(b) Ingenuity helpful in lessening tediousness of record making.

6. Interpreting Data:

(a) Theory of probable error.
(b) Mathematical interpretations of significance of arrays, etc.
(c) Coefficients of correlation.
(d) Plotting of curves.
(e) Significance of curves and graphs.

7. Preparation of material for publication:
   (a) Limiting material to essentials.
   (b) Clarity.
   (c) Readability.

VI. Outline of a Typical Project in Horticultural Experimentation or Research.

The instructor will choose any project he wishes providing it is definite in character but it should be preferably along some rather well-known line in order to permit the assignment of reading matter bearing on the project, as, for example, a field experiment in spraying, soil treatment, or variety testing.

VII. The Literature of Horticultural Experimentation and Research.

Publications of U. S. Department of Agriculture.
Publications of agricultural experiment stations of the world.
Proceedings of many horticultural and biological societies.
Abstracts of horticultural and biological literature.
Books.
(Four periods at least should be devoted to this phase of the subject).

VIII. The Relation of Horticultural Experimentation and Research to Teaching.

Note fundamental connection between research and teaching.
Practical considerations of organization:
(a) in privately endowed institutions.
(b) in state colleges and experiment stations.

Desirable for research man to do some teaching.
(a) Teaching an opportunity to disseminate results of research.
(b) Student gets advantage of first hand contacts and results.
(c) Prevents investigator losing sight of main object of investigation, eg., to teach some new truth.

Desirable for teacher to do some research:
(a) It serves to remind teacher of fountain source of knowledge.
(b) It affords an inspiring example to students.
(c) Adds to prestige of teacher to be a recognized authority in some field.
(d) Teachers are presented with unusual opportunities to discover problems which need to be investigated.

In addition to following the course outline above suggested the teacher should assign recitation material freely from such books as "The Fundamentals of Fruit Growing" (Gardner, Bradford and Hooker) "Text Book of Pomology" (Gourley), "Science and Fruit Growing" (Bedford and Pickering), and others dealing specifically with experimental work in any of the branches of horticulture.

The laboratory exercises which should accompany this course should include the following:

1. Two reports presenting detailed outlines of the plans followed by two successful horticultural investigators in certain typical experiments, the experiments to be named by the teacher.
2. Preparation of definite plans for two typical projects, the projects to be assigned by the teacher.
3. Preparation of a definite plan for one project to be chosen by the student.
4. Preparation of diagrams showing arrangement of plants and plats for correctly laid out and checked field experiments in spraying, soil treatments, and varieties.
5. Preparation of forms for recording data of various types of experimental work.

There should also be laboratory exercises designed to strengthen weak points in the preparation of individual students for research careers. These exercises may be varied to meet the need of the individual student or fitted to the season of the year. Generally they should deal with some specific piece of training necessary to the successful pursuit of some definite branch of horticultural research. Examples of such exercises are as follows:

1. Hybridization of certain flowers in the greenhouse, or out-of-doors if the season permits, in preparation for work in plant breeding or problems of pollination.
2. Practice in histological sectioning of plant material in preparation for studies of various kinds in fruit bud formaation, root growth, storage of carbohydrates, etc.
3. Preparation of grafting material for studies in stock and scion relationships.
4. Practice or observation of actual experimental work in progress.
5. Supply students with uninterpreted data from supply usually available and let them tabulate and summarize it for themselves.

Each of the exercises suggested above will require a number of periods and additional exercises adapted to local needs will readily suggest themselves to every teacher of the subject.

The "Probable Error" in Horticultural Experiments*

By KARL SAX, *Maine Agricultural Experiment Station, Orono, Me.*

MOST horticultural experiments ultimately resolve themselves into a comparison of varieties or differential treatments between plots. It is necessary, then, to determine the probable errors of the difference obtained between two such contrasted plots, or rows of trees. There has been a tendency among certain horticulturalists to avoid statistical methods in interpreting results, due, perhaps, to the conflicting or unsatisfactory results obtained. The usual method of obtaining probable errors is subject to two sources of error due to: 1, the comparatively small number of trees usually involved and 2, the assumption that there is no correlation between the trees or plots which are being compared.

We will consider first the errors due to the small numbers of individuals. The probable error of the mean is dependent on the number of individuals and the value of the standard deviation since P. E. = .6745 σ/n. If the number of individuals is comparatively small, say less then 20, the value of the standard deviation found will usually be less than the standard deviation of the true population. If the standard deviation is less than the true value then the probable error will be correspondingly decreased. Pearson (5) has presented a table showing the constants necessary for the correction of the standard deviation of small samples. In order to obtain the most probable value of the standard deviation, the standard deviation obtained must be divided by the constants given.

The effect of Pearson's correction factors can be well illustrated by a practical application. Random selections were made from the yields of the 59 trees in the New York fertilizer plots (1) for the year 1923. Sixty selections were made for 4, 8 and 16 trees respectively. The uncorrected and corrected average standard deviations and probable errors are shown for the various groups and for the total population in Table I. It is evident that with small numbers of trees the standard deviation and probable errors are too low and that the corrected standard deviations for small values of *n* closely approach the standard deviation for the total population.

In Bessel's formula for the probable error there is evidently an attempt to correct for the small number of individuals, but the results presented in Table I indicate that it is not in accord with Pearson's corrections for small values of n.

The second source of error in obtaining the probable error of a difference is in the assumption that the two distributions under con-

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TABLE I.

Showing Decreased S. D. and P. E. when calculations are Based on Small Numbers, and the Constants Obtained with Pearson's Correction Factors and with Bessel's Formula.

Number of Trees Selected	Average		Corrected		Bessel's
	S. D.	P. E.	S. D.	P. E.	P. E.
4 Trees.........	181	61	227	76	70
8 Trees.........	213	51	235	56	54
16 Trees........	226	38	237	40	39
59 Trees.........	231	20	235	21	20

sideration are not correlated. The usual formula used for obtaining the probable error of a difference between two means is

$$\sqrt{P.\ E._1^2 + P.\ E._2^2}$$

The true standard deviation of a difference is however, (8)

$$\sigma^2 a\text{-}b = \sigma^2 a + \sigma^2 b - 2r_{ab}\ \sigma_a\ \sigma_b$$

The complete formula for the probable error of a difference is consequently

$$P.\ E._{a-b} = .6745 \sqrt{\frac{\sigma a^2 + \sigma b^2 - 2r_{ab}\ \sigma_a\ \sigma_b}{n}}$$

The last term of this formula has commonly been neglected because it has been assumed that there is no correlation between the two distributions under comparison. In most horticultural experiments there will be considerable correlation between the trees or plots due to the effect of soil heterogeneity, and if yields are taken over a series of years there will be a very high correlation between the adjacent plots due to the effect of varied climatic conditions from season to season. This can be illustrated from some of the results obtained by Hedrick in New York (1, 2). If, for instance, we compare plots four and five in his fertilizer experiment we can compare the total yields of the two plots for 13 consecutive years. When comparisons in yields are made, using the usual method for obtaining the probable error of a difference we find that the odds are 4.6 to one that plot four has yielded more than plot five. There is, however, a very high degree of correlation between plots of four and five due to the effect of the various seasons. We find that the value of r is equal to .96. Using the value of r as approximately .9, (since with small numbers the correlation coefficient must be reduced by a correction factor (6) we find that the odds that plot four has been more productive than plot five are about half a million to one.

The effect of the correlation between two plots on the probable error of the difference is also well illustrated in a variety test of oats reported by Love (3). Two varieties of oats, Great Northern and Big Four were compared for nine years. Great Northern yielded on the average 7.4 bushels per acre more than Big Four. The probability that such a difference is not due to chance when calculated by the usual method was only 5:1 and could not be considered significant. When, however, the correction is made for the correlation between

the two plots, due to seasonal variations, we find the odds are about 1,500 to one that Great Northern is more productive than Big Four.

The use of the complete formula for obtaining probable errors involves considerable labor and is also unsatisfactory in some respects because of the small number of individuals frequently involved in obtaining the correlation coefficient between the two plots. Fortunately a method is available which takes into consideration the effect of small numbers and by pairing the observations avoids the influence of climatic and soil fluctuations on individuals within each frequency distribution. This method is known as Student's method as it was developed by an investigator who signed himself "Student" (7). Love has recently called attention to this method and has calculated tables showing the odds for different values of Z. The probable error of the difference according to Student's method may be expressed as

$$Z = \frac{\Sigma D/n}{\sqrt{\Sigma D^2/ n-(D/n)^2}}$$

where D is the difference between each pair of observations and n is the number of paired observations. By looking up the value of Z in Student's tables or in Love's (4) modification of Student's tables the probability is evident that the differences are not due to chance.

It is obvious that if two plots are compared over a series of years the climatic differences will usually influence the performance of trees much more than the differential treatment. When the standard deviation for the yields in different years is obtained it will be too high because of the variation in seasonal differences. In other words, the variation found is not dependent on random sampling but is due to the effect of season and soil. Likewise adjacent rows of trees might vary considerably due to soil heterogeneity. Now in Student's method it makes little difference how much variation occurs from season to season, or from plot to plot, due to climatic and soil variability. Since the comparisons are made between adjacent trees or between plot yields obtained in the same year the differences obtained will be comparable. Accordingly Student's method would be expected to give approximately the same results as the usual method using the complete formula for the probable error. This is found to be the case. When plots 4 and 5 in Hedrick's fertilizer experiments are compared by Student's method we find that the value of Z is 2.0 and that the odds are much more than 10,000 to one that plot four is more productive than plot five. Likewise, in comparing the two varieties of oats recorded by Love we find, according to Love's analysis, that Student's method gives odds of about 900 to one that Great Northern is more productive than Big Four. These figures compare favorably with the odds shown by the complete formula for the usual method of obtaining the probable error of a difference, taking into consideration the fact that the value of r can only be approximately determined with small values of *n*.

With "Student's" method of obtaining the probable error of a difference the climate and soil should be as uniform as possible for any given pair of observations although different pairs may vary

considerably. While it is not difficult to obtain uniform climatic and soil conditions for pairs of trees it is difficult to obtain trees which are inherently alike because of variable root stocks and other factors. For this reason it is especially desirable to use as large numbers as possible in horticultural experiments.

The number of pairs of trees or plots necessary in experimental work depends on the standard deviation of the differences in performance of paired trees and the percentage of difference desired between the check trees and those receiving differential treatment. With the percentage difference desired and the value of the standard deviation known it is a simple matter to determine the number of trees necessary to give odds of 30:1 that one plot will be more productive than the other. For instance, if we wished to start a new series of experiments with Hedrick's fertilizer plots and desire 20 per cent differences between contrasted plots the number of trees necessary to give significant odds for such a difference can be found by dividing 20 by 50 (the approximate standard deviation in terms of percentage of the mean yield for 40 pairs of trees for 1923). This gives us the value of Z and on looking up 30:1 odds for $Z = .4$ we find that 25 pairs of trees are necessary. If, however, yields are to be obtained for a series of years the standard deviation of the differences will be reduced and only 11 or 12 pairs of trees will be needed. The number of trees necessary for reliable results must be calculated for each orchard because of differences in age of trees, soil heterogeneity and variability of root stocks in different orchards.

We may conclude then that the probable error of a difference as usually determined is subject to several errors. The complete formula for the P. E. of a difference is reliable because it takes into consideration the correlation between the two frequency distributions under consideration. Essentially the same results can more easily be obtained with "Student's" method and accordingly this method is recommended for most types of horticultural data.

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Methods of Interpreting Results of Horticultural Experiments

By R. D. ANTHONY, *Pennsylvania State College, State College, Pa.*

IN THE first place it should be thoroughly understood that no method of interpretation is so reliable as to justify any investigator in his failure to use common sense and good judgment in drawing conclusions from his results. Statistical methods cannot prove the accuracy of our conclusions, they simply aid in determining the reliability of the data from which we draw these conclusions.

Horticulturists have two types of problems: those in which the number of individuals is so large that the normal variability of these individuals does not seriously influence the results of our studies and those in which the small size of the population makes it necessary to determine the influence of individual variation. More and more we are finding that our problems, even with vegetables, are shifting from the first type to the second.

A variation much more troublesome to find and to evaluate is that caused by soil differences. In an attempt to decrease this variation we are using much smaller plots with more replicates, but as the size of the plot decreases the importance of the individual increases. If we are to secure the largest return for our outlay of time and money the unit of measurement in practically all fruit experiments and in many vegetable experiments using cabbage, tomatoes and corn should be the performance of the individual rather than of the plot.

The following are some of the steps to be considered in a statistical analysis of horticultural data: 1. Select those factors for study which most accurately determine the response to the treatment under study. 2. Determine the number of individuals necessary to reduce the errors due to their normal variability to a negligible point. 3. Find proper values for the errors due to the variability of our data. 4. Detect and eliminate as far as possible soil variations. 5. Rearrange the material in such ways as to reduce all measurable errors to a minimum.

The writer does not feel sufficiently familiar with vegetables to make any suggestions as to the measurements which should be taken

in experiments with them. He has been impressed with the paucity of information relative to the performance of the individuals in vegetable experiments. How many vegetable investigators can supply the coefficient of variability for their material?

While yield records with fruit must form the ultimate criterion, they are liable to serious errors and should be correlated with plant growth whenever possible. There are a number of ways of accomplishing this. In several recent experiments the weights of fillers have been used. Of necessity, only a limited number of results can be secured in this way. Weight of prunings is one of the common measurements and with grapes and small fruits has, probably, a high value when known for the individual rather than the plot. A few investigators are using the length of annual growth—a valuable factor but somewhat laborious to secure. Waring, in the Seventeenth Annual Report of this Society, finds a high degree of correlation between trunk circumference increase and yields in experiments with apples.

To determine the number of individuals necessary "to demonstrate satisfactorily the significance of various percentage differences in the average gain between two lots," Mitchell and Grindley in Illinois Bulletin 165 have developed a formula which involves the number of individuals, the percentage differences when the odds that these differences are significant are at least 30 to one, and the coefficient of variability. This is very usable in determining the probable accuracy of experiments already sufficiently far along to enable us to compute the coefficient of variability and has considerable value in aiding us to settle upon the proper number of individuals for new experiments when we know approximately the variability of the material to be used.

For the betterment of horticultural research it would be excellent if we were to adopt the view that an average is incomplete until its probable error is known. Certainly two averages should never be compared without their probable errors. There has been some confusion in interpreting this error. It shows simply the degree of variability of the values entering into the average—a variability which may be due to the use of too few individuals, to soil differences, or to any of a dozen different factors. Even when the probable error of the difference between two treatments is small enough in proportion to the difference itself so that statistically the difference is significant all that we are justified in saying is that these two plots are clearly different. This difference may still be due to something other than our different treatments. The answer to this seldom lies in the realm of mathematics. It usually depends on our intimate knowledge of the history of our soil and a close study of all the many details of the experiment. Examples of the use in horticultural experiments of Bessel's formula for the probable error of the mean can be found in Pennsylvania Bulletin 173.

The nightmare in all field experiments is soil variation. The use of small plots with many repetitions has been our usual way to avoid this trouble, but in many soils large changes may take place in such a

short space that even this method does not satisfactorily eliminate this variable and such a layout with tree fruits is troublesome to handle. Frequently, especially in some of the older experiments which were planned before we realized the extreme importance of soil uniformity, there are progressive soil differences in the plot which result in considerable variation in yield or plant growth and consequently a high probable error by Bessel's formula. The most usable test to eliminate to a large degree the influence of such a variable is the so-called "Student's" method of analysis described in Volume II of Biometrika. This method can only be used in this way when the material is so arranged that adjacent individuals can be compared. It is based on the differences between the members of a series of pairs and consequently deals with much smaller variables. An example of its use in this way may be found in Pennsylvania Bulletin 173. The use of "Student's" method does not eliminate the influence of a soil variation which progresses uniformly across a series of plots from row to row, in fact it usually accentuates such an influence. Because it does accentuate a difference which influences one row more than another we may use it to detect such soil differences if we have two or more similarly treated rows in a block.

The variation in yield from year to year also introduces a troublesome factor into our interpretation of results as again we have averages with large probable errors. "Student's" method can be used to study the differences between two plots from year to year and thus decrease the amount of variation to a considerable degree. Percentage differences can be used to bring about a still further decrease.

Although this paper has dealt almost entirely with the interpretation of experiments already established, a word of suggestion for the planning of new experiments may not be out of the way. This year it became necessary for our Department to establish an experiment in a commercial apple orchard to test two fertilizer treatments. We wished to be able to detect differences as small as 10 per cent. By the use of the old plot methods this would have been practically impossible. By planning to use "Student's" method we were able to select enough well balanced pairs of adjacent trees in the five acres available to us to give us large enough numbers so that we have a reasonable chance to show differences as small as that desired. A number of experiments in other states have also been planned on this method.

The Advantages and Disadvantages of Organization and Standardization in Horticultural Research

By W. H. CHANDLER, *University of California, Berkeley, Calif.*

IN ACCEPTING the invitation of the committee to prepare a paper on this subject, I did not assume that I could make an original contribution. It would be impossible, it seems to me, to learn by direct study just how the output of new truth would be influenced by any environmental feature of the workers; except the indispensible one of time and equipment. And so, what I shall say will be frankly only opinions.

I believe that in horticultural education the time has come when a certain kind of organization and standardization is inevitable if we are to make progress in the evolving of new truth; and even if our teachings are to be more beneficial than harmful to the industry.

The nature of that standardization is determined by the development of science. In earlier stages rather simple experiments with some brilliance of observation and interpretation sometimes yielded rather far reaching results. However, as the different sciences have grown there have been developed more refined techniques. The literature, that is, the record of the experiences of scientists, becomes constantly more complex. In the study of the technique and the evaluation of the literature of a science, the worker develops the spirit by which the scientist is known; a spirit of tolerance toward the views of other workers, but one that takes nothing for granted, examines every promising or popular theory, or apparent discovery, in the light not only of his own experiences, but also of a careful study of the experiences of all workers in similar lines; a spirit that makes laborious effort in the laboratory or the library not only endurable but interesting. The highly trained scientist, unlike the man who tries to adopt the scientific life without learning it, seldom wants to undertake a large number of projects and hire the work done.

It is this scientific spirit rather than any artificial code of ethics that, it seems to me, must be depended upon to regulate the lives of the workers in relation both to their problems and to their institutions. And so the organization and standardization that is inevitable for fruitful scientific work is that which promotes in the workers skill and industry in a technique, critical knowledge of a rather broad scientific literature, and the scientific spirit.

In horticultural work it seems that the time has passed for the simple field experiment that is not associated with more fundamental studies of the responses of the plants and interpreted in the light of a comprehensive knowledge of the literature of plant science. The horticulturist must not merely know how to manipulate trees and other plants. He must have a critical knowledge of the literature concerning plant responses and a technique by which he can study his plants fundamentally. It seems to me that the most gen-

erally useful technique will be in biological chemistry. Thus, the organization that can be most helpful in horticultural research is the graduate school that stresses fundamental training in plant science.

A man with adequate training, obtained in a graduate school or by his own efforts working separately, has his problem suggested to him in part through his observations in practice, but more largely through his broad knowledge of the literature. He estimates the amount of work probably necessary for the solution of the problem and decides how much he must narrow his efforts; that is how small a part of the general problem he can wisely undertake to study. He keeps in touch with other workers in that particular, rather narrow field and decides whether or not the angle from which he is approaching the problem is sufficiently unlike that of other workers that he may wisely proceed. He also advises with strong men in closely related fields. He learns from the literature what methods have given the best results in similar studies. If certain chemical analyses are to be made he seeks dilligently in the literature for all improvements in methods that are supported by strong evidence and endorsed by workers of standing. Then, if someone will furnish him funds for equipment and perhaps for routine assistance, he is organized and standardized in so far as that problem is concerned. He may either use the standard methods which may be reasonably certain to yield results of some value, but perhaps with the value reduced by the imperfections of method or he may spend time in improving the standard methods or strike out in a new direction with the hope of making more far reaching discoveries but perhaps with the possibility that he will obtain only negative results. We need men working in the former conservative way and in the bolder way; and it seems to me that only the worker should decide which way he will follow.

While I think the great organizer of research is the scientific literature, the record of the experiences of workers now and in the past, I believe there are ways in which well trained workers can be helped. I have generally thought that a director in an agricultural college, giving much of his attention to the research of others is likely to be more harmful than beneficial; and I still believe that is true of a man who actually attempts to direct the work of others. However, I have come to believe that there are minor chores through which a man called a director may be very helpful to research in an institution; provided he does not become merely an administrator, but maintains and broadens his contact with the scientific literature. Even though an institution may be lavishly supplied with funds there will soon come to be a condition such that some excellent young men will not be well supported. It will never be possible for all work being done in an institution to be supported in accordance with its merit. For the merit of work is not known with certainty until it is completed, often not until long after it is completed. Further, an effort to make very exact division by reducing allotments to some workers and increasing those to others is likely to do more harm, through the ill feeling produced, than it does of good through equalizing support.

However, in all institutions having reasonably good support, there will be inequalities so evident that a fairly courageous man can, without causing serious discontent, make adjustments in funds that will help many promising young workers. A department or group of workers may require expensive support during certain stages in the progress of a piece of work; and if no one is giving close and sympathetic attention to the distribution of the funds such departments or groups will continue to receive large sums of money when a smaller allowance would enable the work to be done satisfactorily. And workers with good training may be able to describe in an effective way work they want to do, but may be still ineffective in carrying forward any project. If the funds are administered without the rather intimate and detailed attention of a director such men will certainly waste a lot of money while modest, patient, effective men may be without support. Further, some good workers are unnecessarily extravagant. I have seen in a department four or five laborers pitching hay onto one wagon no more rapidly than two should have done. Yet good workers in the same college were unable to obtain funds to buy equipment most urgently needed. I do not mean to say that good but extravagant workers should not be extravagantly supported. A little truth is worth a lot of money. But in supporting such men the interest of the other workers should be considered. It seems to me that a large part of the funds of an institution should be divided annually; and the groups or departments should be trusted to use it wisely. However, there should be a considerable part in the hands of the director for helping individual workers in emergencies; and when in one year the director makes an allowance from that emergency fund he should not be considered thereby to have committed himself to make a similar allowance in a succeeding year.

A director who cultivates a scientific spirit in his own life and trusts it as the best guide for the workers can do at least a little to cultivate that spirit in his institution and to oppose the propaganda spirit that seems to me to be doing so much harm in the agricultural colleges. He can use his influence to have promotions in his institution made in the light of the scientific spirit rather than for a showy personality, or for success in propaganda. He can protect the workers against the encroachment of people who think the colleges are serving the farmer best when they try to do his chores; and even against some of the urgent requests of some of the agents of good farmers' organizations. The college should, of course, be anxious to be of the greatest possible service to the growers; but if men should be forced to neglect work in progress in order to take up every new problem that is suggested by some active agent of some organization, few if any projects would ever be completed and the contribution of the college to the farmer would be turmoil and disappointment. In the main the research of today can not solve the pressing orchard problems. Such problems must be solved in the light of the research of the past. It seems to me that the extension men are best fitted to study the relation of established principles to local orchard problems.

Much time seems to me to be wasted in discussing possible cooperative projects. A man can always see where his work is connected with problems in another man's field; but he doesn't always realize that the other man knows it, but is busy with other problems. The creed of cooperation in research is a very old one; but I think it is true that nearly all we know has been learned by men working separately, or with friends of their own choosing, and somewhat jealous of their own ideas. Workers must certainly be trusted to arrange their own cooperations. There should be in an institution no sharp boundaries limiting a man's research activities; and any man should be free to seek the advice of any other man in the institution; but a man has no right to expect another to come and live with him in his research. There are of course many other useful services that a man holding the title of director may do, but his influence in giving direction in research will probably be much less than that of many other men. Those who have the greatest influence in giving direction to research are the scientists who do striking, original and far reaching pieces of work, or who propose far reaching theories. I believe it would not be an exaggeration to say that Kraus and Kraybill have with one paper exerted a greater influence toward the development of a sound effective horticultural research than have all the directors of all the experiment stations of the country.

I know of one brilliant and effective department in an arts college in which no one is head, each worker being responsible only to his profession. While such a plan has seemed to work exceedingly well in that department of history, I do not believe it would generally work well in departments in a college of agriculture where the need of large funds brings sources of friction into a department, and where important public contacts make necessary some kind of departmental supervision. However, as to support for research, I do not believe that the powers or duties of the head of a department should be very nicely defined. I think the director should generally have the right to discuss with each individual the progress and needs of his work and to take some action when any promising man in a department seems to him not to be receiving the support he should have. However, I would not want such a right of a director to be very sharply defined. I would want enough indefiniteness as to the powers and duties of the worker, the head of his department and the director that the one who is most nearly right in a particular case will tend to prevail, rather than the one who is most nicely following the official rules.

I have generally disliked the idea of writing out a project outline and having it examined with the purpose of approval or disapproval by a director, or by any one else. I think it is to be assumed that a man will discuss his problem with men in whom he has confidence and that when started it will have had much more careful consideration than could be indicated in any brief formally written project plan. And, I still believe that if a director depends upon such formal project outlines and upon project reports as his chief means of keeping in touch with the men of his institution he will know very little

about his men. However, I believe that the excellent men who have had charge of the Adams Fund, have by means of the formal project outline caused much of that fund to be used for work of permanent value, rather than for work of an ephemeral nature, and have thereby made a great contribution toward the sounder development of agricultural education.

One of the most valuable agencies in coordinating horticultural research is the American Society for Horticultural Science. Perhaps no other privilege is of as great value as that of hearing one's own work and that of others discussed critically. It should be of as great value to a man in his extension or his teaching as in his research activities. My only suggestion for improvement would be to spend all the time reporting and discussing new truth, and none with papers like this one. My only justification for this paper is that Professor Blair tempted me and I was like an old physician who, when asked why he continued to work, said it was to keep the other rascals from getting the practice.

In brief, I am in favor of such organizations as we now have insofar as they do not attempt to give direction to research by any other method than discussion and helpful criticism, but I believe that any more formal organization and coordination would make for stagnation. I have not mentioned that old bromide about what organization has done for business. I have too much respect for the intelligence of men who are making such a fine lot of research reports as this year's program of the society contains. For the man who wants more organization and standardization, I would suggest, that if he now has an effective scientific technique, he spend a considerable amount of time renewing his contact with the scientific literature. There he will find the system that not only gives direction to sound research, but has been, perhaps, the most dominant influence in shaping the progress of the human race; an influence that has gone far toward replacing fear and superstition in men's lives with the serene courage that comes with understanding. With the guidance of this system of literature, supplemented by abstract journals, reference works and critical treatises, and with the help of societies such as this, through which he keeps in touch with the work in progress, he can be certain that whatever he does will find its place and be effectively incorporated in the system of knowledge; and he will have the incentive of knowing that it will be incorporated as his contribution. I do not believe that with all the boasted efficiency in business organization there has been developed such a system of cooperation by which all work is effectively used in building up an incomparably useful structure and yet each man has the inspiring incentive of having his name associated for all time with the contribution that he makes.

Advantages and Disadvantages of Organization and Standardization or Unification of Effort in Horticultural Research

By C. G. Woodbury, *National Canners Association, Washington, D.C.*

Introducing the Discussion

MAY we point out what seem to us some of the shortcomings of horticultural research? Then perhaps we may see how far cooperation and co-ordination of effort may be expected to correct them.

Among these shortcomings is lack of training of workers in those sciences whose aid must be invoked to solve the problems of horticulture. Another weakness is lack of experience of workers in the art of horticulture. Another is the diversion of effort and energy from research by the multitudinous duties of administration. An occasional handicap, I suspect, is such a preoccupation with the physical accessories of research that real progress in achievement is retarded. There are, doubtless, some men in some institutions who are not making the research contributions they might because of lack of funds and lack of equipment. For many years I have had the feeling that the highly departmentalized organization of most of our experiment stations has been a considerable handicap to progress.

Research in Horticulture,—What is it? Would one dare say that it is almost a contradiction in terms? Research I shall not attempt to define. There is little disagreement, I think, as to what the word research stands for. Few of us may be imbued with its spirit. Still fewer of us may be able to use its methods, but most of us feel that we know research when we see it. It connotes a practiced and skillful use of the tools and the methods of science applied to the extension of the boundaries of knowledge. In horticulture I am not sure that research is possible, for horticulture is an art, not a science. Maybe it will be a science some day. Perhaps some of us feel that the day has dawned, but I doubt whether it has. This is not an expression of a spirit of pessimism. We are making progress in horticulture, I am convinced, but what is horticulture? In the special sense in which we use the term I claim a measure of validity at least for some such definition as this: The application to the production of a certain group of crops and plants arbitrarily chosen, of all the available knowledge in a wide range of science and in a wide range of empirical practice.

Research in horticulture, if the term may be allowed and if scientific inquiry does not cease to become horticultural in becoming scientific, must include the contributions of quite a family of chemists, of soil specialists of several denominations, of bacteriologists, of plant pathologists, of entomologists, of specialists in different branches of botany including taxonomy and morphology, of students of genetics and plant breeding, etcetera, ad libidum.

The problem is "How may the contributions from several more or less fundamental branches of science be speeded up, made more productive, more serviceable both to abstract science and to a great group of agricultural industries by being co-ordinated as between individuals or as between institutions, or both, and by having introduced into the process somehow a greater degree of cooperation,—a greater expression of the group method of investigation?"

There is no doubt in my mind about the need and the opportunity for co-ordination in research within institutions. The chemist, the horticulturist, the agronomist, the plant pathologist, will, I believe, find themselves associating with each other more freely in research work as they forget their artificially erected departmental barriers. In solving a crop problem there is almost always need for a pooling of information and for group effort. Each individual of the group may work alone, unco-ordinated and unregenerate, in the field of his speciality. The crop problem is nearly always a composite. Seldom will it be solved completely through the application of research results from a single field of science. Therefore, by all means encourage each specialist to bring his contribution freely and often to his colleagues and find out how it fits into the picture. The bringing about of this kind of correlation or co-ordination of effort is the job of the administrative officers. Within the department it is the job of the department head. As between departments it is the job of the dean or director. The degree to which it can be done harmoniously, the degree to which such a spirit and atmosphere can be created as will cause the workers in several fields to wish to associate themselves together voluntarily is one measure of the success of the administrative officer.

Advance in research depends upon the birth of creative ideas in the brain of the research scientist. The processes of conception, gestation and delivery in the realm of ideas are almost as much individual processes as in the realm of biology. Ideas to be sure, like persons, have parent ideas which precede them, and offspring which carry on the family. The bringing forth of a new creative idea is, however, no more of a cooperative or group enterprise in the one realm than in the other.

Cooperation of a sort is nevertheless, in my opinion, desirable. Cooperation in research, however, if imposed from the top down, is unlikely to be scientifically productive and profitable. Cooperation to be effective must be real. To be real it must be voluntary. It must be a creation brought about through the processes of evolution rather than a creation by administrative fiat.

Cooperation in research within an institution, or between institutions, or between individual workers in different institutions, may be advantageous if natural, voluntary, and untrammeled by too much administrative regulation. Over-administration, or over-organization, may easily operate to diminish initiative and to retrict freedom. The development of new knowledge is almost always n individual, not a collective, function. During the war emergency prodigious efforts were made in the direction of co-ordinating re-

search. Progress was certainly speeded up and results were achieved more promptly than would have been possible otherwise. Is it not true that progress was made rapidly because a type of organization was developed which not only permitted but compelled severe intensive effort, with prompt testing of provisional hypotheses and prompt verification or rejection? Even in the case of wartime research, however, is it not true that the results achieved were in each instance the product of individual minds functioning individually?

Without the stimulus of the war psychology and the powerful motives of patriotism, how can we secure in normal times the intensive effort, the enthusiasm of spirit, the eagerness to pool results which were characteristic of war research and which should be a normal characteristic of any highly productive research institution? How can we secure freedom of the individual research worker plus such co-ordination as will cut out lost motion and waste of time? Expression is often given to the feeling that there is too much administration, too much organization, for the research spirit to function freely. Is this a just charge? I think not as applied to horticulture. I am inclined to think that usually there is too little administration rather than too much, although I realize that I am speaking from a viewpoint which may be prejudiced by administrative experience, and because I am not myself numbered in the elect circle of creative research workers. The real need, I suspect, is for rather more "administration," but the most helpful relation of "administration" to "research" can be expressed only in qualitative terms. It is the *kind* of administration not the *amount* that is of importance. Of the right kind there is seldom enough.

Horticulture is making progress, although slowly, in learning how to use the tools of science. Co-ordination of effort will follow if there is sufficient opportunity and encouragement for workers in related fields to get together and build that foundation of mutual accord and personal liking without which a super-structure of genuine cooperation cannot be built. In most of our institutions the travel privilege is being more and more restricted. Out of state travel is becoming more difficult through the type of fiscal organization which is growing up in many of our states. Workers in related lines should be able to keep in touch with each other's progress through frequent visits and perhaps through regional conferences. No elaborate administrative machinery is required.

Much may be said for the development of co-ordination and cooperation through the United States Department of Agriculture. There are certain offices in the Department already through which, as through a clearing house, freedom of intercourse, freedom of interstate travel, and regional conferences on related research problems, are actively promoted. It is the deliberate policy in these offices to associate every outstanding worker in the field with the Federal group. This has not meant Federal interference nor Federal dictation, but it has promoted the development of acquaintance and in some cases a specialization of effort which has meant more rapid progress.

The foregoing remarks are intended only to suggest a viewpoint from which the program topic may be discussed. If the shortcomings of horticultural research referred to are real and not imaginary, it is obvious that cooperation or coordination of effort will not correct them. Cooperation will not supply the research spirit where it is lacking; cooperation will not correct deficiencies in the technical and scientific equipment of the worker, it will not remedy ignorance of the art and practice of horticulture, it will not take the place of hidden structural weaknesses in our professional dwelling. It may be that our first responsibility is to remedy these weaknesses and defects. Where they do not exist then let us focus on our problems regardless of departmental lines, let us remember that as a group we are exponents of *applied* science, that we are in the highest and finest sense in the public service, and let us bring to bear on the solution of the specific crop problem before us all that *all* the biological sciences that underlie agriculture, can contribute. Undoubtedly this requires a better co-ordination of effort, especially within institutions, than is at present typical of our college and station organizations.

Perhaps by official resolution and active committee work we may do something toward counteracting the increasing travel restrictions in state institutions and promote that closer acquaintance and more frequent conference among workers in related fields which is a prerequisite of any effective cooperation.

The relations with the Federal offices should be made the subject of a special discussion. The opportunity is open to bring about a new and exceedingly helpful relation to horticultural research through a large expansion of the contacts between state and federal workers. This may be difficult, but certainly it is worth while.

College Teaching of Horticulture*

By Dr. A. C. TRUE, *United States Department of Agriculture, Washington, D. C.*

THE papers on college courses in horticulture read at this meeting have been very interesting. They show that college teachers of this subject have given much attention to the planning of these courses and have considered carefully the relations of science and practice in collegiate instruction in horticulture. In general I agree with the authors of these papers that the colleges ought not to be expected to turn out experts in the practice of horticulture. Expert practice can only be attained through actual experience in the fields, gardens or glasshouses and contact with commercial horticulture.

*Upon the invitation of President Dorsey, Dr. A. C. True spoke extemporaneously on the college teaching of horticulture and later wrote his remarks for printing in this annual report.

But the colleges can give the student a broad basis for success as a horticultural practitioner by instructing him in the science underlying the art and in different modes of particular practices so that he will not only know how to perform them, but will also understand the reasons for them and their varying advantages. Such knowledge is also essential to the teacher or investigator of horticultural subjects.

There has recently been much criticism of college teaching in general. Many educational authorities believe that there is better teaching in the secondary and lower schools than in colleges. They attribute this largely to the fact that college teachers come to their work after long courses of study, which in their advanced ranges have been highly specialized. The young college teacher may, therefore, have lost, or never gained, a broad understanding of the subject he has to teach and its relations to other subjects in the curriculum. He may not be able to appreciate the mental status of the students who are seeking an elementary or general knowledge of the subject or even of those who are entering on the initial stages of a specialty.

The traditional view of college teaching has been that if one is a thorough scholar in his subject he will be able to teach it well. But experience has shown that this is not always so. The most eminent scholars on college faculties are sometimes poor teachers. Sometimes this is so because they have been so much interested in research or in book writing that they have given comparatively little attention to their teaching. In recent years probably undue emphasis has been laid on research as if this is the most important function of the college teacher. Almost all educators would agree that he should be interested in research and carry on a certain amount of it in connection with his teaching. But it is unfortunate if he becomes so devoted to research that he neglects his teaching.

Textbook and lecture methods are also responsible for much inferior teaching in colleges. It is so easy to give out pages in a textbook for a lesson or to read a lecture prepared long ago that college teachers have often yielded to the temptation to make little effort to create the live interest of their students in the classroom. Meanwhile the instructors have other matters engrossing a large share of their time and attention.

College teachers have also greatly neglected the study of psychology and the principles and methods of teaching. Indeed there are still some college teachers who despise such studies. But there has recently been quite an awakening of interest in these matters in college circles and much earnest consideration of ways to improve college teaching.

The land-grant colleges through their association have taken an active part in this movement. Their committee on instruction in agriculture, home economics and mechanic arts, of which I have had the great honor to be chairman, has for several years devoted itself to studies relating to the improvement of college teaching. Its reports on this subject may be found in the proceedings of the Association of Land-Grant Colleges.

One result of the discussion of this matter in the association has been its approval of a recommendation of the committee that beginning with 1925 candidates for positions on the faculties of these colleges must have professional training in education.

In recent years educators have given much attention to the development of the problem or project method of teaching. This involves the abandonment of the logical presentation of a subject after the manner of the ordinary textbook or course of lectures. The aim is to build on the knowledge which the student already has and to put before him a series of concrete problems in a new subject in the solving of which he will deal with both the theory and the practice. Such a subject as horticulture would seem to be well adapted for the development of the problem method in teaching it. To do this would require much study by the teacher with reference to the choice of problems and the development of the instruction so that the student would make satisfactory progress in the subject as a whole.

This method would, I presume, take into account the local environment of the college so that the teaching of horticulture in a particular institution would begin with the consideration of problems growing out of conditions in its immediate vicinity.

To develop a good course in horticulture by the problem method would necessarily involve a thorough job analysis of the different horticultural enterprises in olericulture, pomology, floriculture, landscape gardening, etc. Such analyses of enterprises within the general agricultural field are comparatively new. The Division of Agricultural Instruction in the United States Department of Agriculture has been making some of these in cooperation with the Federal Board for Vocational Education. These have been made with special reference to the requirements of secondary education, but might interest college teachers who are looking into this matter. They are published in bulletins issued by the Federal Board for Vocational Education.

Not being an expert in horticulture I would not presume to attempt to show how a college course in horticulture could be worked out on the basis of the problem method. I am simply suggesting that college teachers of horticulture would do well to look into this matter. It is my belief that success in developing instruction in horticulture, as in other vocational subjects, on this basis would do much to promote interest and efficiency in the work of the college relating to this very important subject.

The Effect of Pruning and Staking upon Production of Tomatoes

By ROY MAGRUDER, *Ohio Experiment Station, Wooster, Ohio.*

THE question of the practicability of pruning and staking tomatoes for early market production was recently raised in Ohio by one of the leaders in the vegetable gardening profession from the East. As a result of experiments in his state he said the growers were discontinuing the practice since it had been proven to their satisfaction that it was not profitable.

Our growers, however, were satisfied that the advantages more than counterbalanced the disadvantages and looked with skepticism upon any change in methods.

An investigation of the literature on the subject revealed very little work that would be applicable to Ohio conditions. There seemed to be a difference in the effect of pruning and staking on earliness as reported from the different sections of the country. So in order to determine the solution for Ohio conditions an experiment was conducted this past season to determine the effect of pruning and staking on (1) the production of early fruit, (2) the size of fruit, and (3) the total production.

PLAN OF EXPERIMENT

Seed of Livingston's strain of Bonny Best was sown in the greenhouses April 10, shifted into flats 2½ by 3 inches apart, April 20, and set into the field June 17. Continual rains prevented setting any earlier, but the plants were in good condition and had not blossomed when set. A good rain soon after setting started the plants into growth and a very good stand resulted.

The rows were four feet apart and the plants two feet apart in the row. A unit row consisted of 20 plants with a two foot space between units. Each treatment was replicated six times, the unpruned row being systematically distributed through the plot.

Four treatments were given as follows: unpruned and unstaked, staked and pruned to one, two, and three stems. Pruning was done by removing the suckers at least once each week. The pruned rows were tied to the stakes with soft twine four times during the season.

The soil was a silty clay of moderate fertility which received a fertilizer treatment of 150 pounds of nitrate of soda, 500 pounds of acid phosphate and 10 tons of manure per acre.

Three applications of 4–6–50 Bordeaux mixture were applied, one while the plants were in the flats and two in the field at 10 day intervals. Septoria leaf spot was very bad and the unpruned rows were practically dead at the last picking of ripe fruit.

The original plan was to pick three times each week on Monday, Wednesday and Friday, following the practice of gardeners, but rain

prevented strict adherence to this schedule. All fruits showing pink color at the blossom end were harvested and a record taken of the number and weight of each picking.

In order to condense the tabular presentation of the data, a week was chosen as the arbitrary time unit. The production given in part one of the table is the total of all the fruit harvested between Monday and Saturday of each week. The first picking was made on Thursday, August 21, and only the one picking was made the first week.

Effect of Pruning on Early Yield

Lloyd and Brooks (6) and Rosa (3) found that pruning did not increase the amount of early fruit while Olney (4), Wicks (2), Whipple and Schermerhorn (7) and Stuckey (1) found that it did increase the amount of early fruit. Stuckey's work is the only one that contains the data in such condition that it is possible to determine the length of the "early" period. This is an important item for if in this work the first five weeks were taken as the early period, pruning would not have increased the amount of early fruit, where as a matter of fact, it did increase it for the first four weeks. Prices drop rapidly after the outdoor stock comes on the market and as Green has shown with actual figures from the Marietta district (5), the first two or three weeks are the most important where price is concerned.

Not until the fifth week did the unpruned plants yield more than the pruned. Of the pruned treatments the single stem produced more ripe fruit during the second and third weeks, and tied with the two-stem the first week. The two and three stem produced the same amount the fourth week, both yielding more than the single stem.

Part 2 of table one shows that on the basis of accumulated total at the end of each week, that the unpruned production was not larger until the end of the fifth week. The single stem total was larger than the other pruned lots until the sixth week from which time the others gradually gained. In all except the second week, the two stem lot produced more than the three stem. A graph from part 3 demonstrated very clearly that the pruned lots produced larger crops of ripe fruit for the first four weeks, the unpruned the larger crops for the next four weeks, and the pruned lots again yielded more the last two weeks. The fact that the pruned lots yielded more the last two weeks is due to the fact that the unpruned vines had been defoliated by Septoria leaf spot and were practically dead by the end of the picking season. The weight of green fruit after frost (part one) indicates the relative amount of green fruit on the vines at that time, but does not show that this green fruit on the unpruned vines was very small and would not have ripened for several weeks while much of that on the pruned vines was almost full size.

Effect of Pruning on Size of Fruit

Lloyd and Brooks (6) found that pruning had slight effect upon the size of fruit while Olney (4) found a definite increase in size in favor of the pruned plants.

Table I.

The Effect of Pruning and Staking upon the Production of Tomatoes 1924, O. A. E. S. Average of Six 20 Plant Replicates in Pounds per 20 Plants

Week Number	I	II	III	IV	V	VI	VII	VIII	IX	X	
Number Pickings	1	2	3	2	2	2	2	3	3	1	
Number Stems	Part 1 Pounds Ripe Per Week										Total Green
*N	.4	1.7	4.8	3.4	25.2	53.9	29.5	35.0	14.3	1.6	2.5
1	.6	3.2	9.7	4.2	16.9	28.5	14.6	25.7	18.4	4.3	26.4
2	.6	2.1	7.7	5.1	15.5	33.7	17.6	23.4	24.1	5.0	23.0
3	.5	2.8	6.5	5.1	14.6	35.1	24.9	31.0	28.9	6.9	27.5
	Part 2 Accumulated Total Production at End of Each Week										Total Ripe
N	.4	2.1	6.9	10.3	35.5	89.4	118.9	153.9	168.2	169.8	169.8
1	.6	3.8	13.5	17.7	34.6	63.1	77.7	103.4	121.8	126.1	126.1
2	.6	2.7	10.4	15.5	31.0	64.7	82.3	105.7	129.8	134.8	134.8
3	.5	3.3	9.8	14.9	29.5	64.6	89.5	120.5	149.4	156.3	156.3
	Part 3 Production By Weeks in Per Cent Comparing with Unpruned as 100 Per cent										Total Ripe
N	100	100	100	100	100	100	100	100	100	100	100
1	150	188	202	123	67	52	49	73	128	268	74
2	150	123	160	150	61	62	59	66	168	312	79
3	125	164	135	150	58	65	84	88	202	431	92
	Part 4 Average Size of Fruit By Weeks										Season Average
N	.143	.173	.177	.237	.355	.361	.334	.252	.204	.148	.239
1	.114	.181	.212	.368	.425	.452	.399	.366	.373	.375	.327
2	.126	.153	.205	.309	.404	.432	.431	.361	.342	.314	.308
3	.119	.181	.225	.347	.388	.426	.448	.356	.340	.325	.316

*Unpruned

This work shows a decided increase in favor of the pruned plants for every week except the first. The single stem shows a slight advantage over the two and three stem plants. It is significant, too, that the average size of fruit decreases rapidly after the sixth week on the unpruned plants while the pruned plants maintain a satisfactory sized fruit to the end of the sesaon.

The average increase in size of fruit for the first four weeks, of the one stem over the unpruned was 19.6 per cent, for the second four weeks 26 per cent and for the entire season 36 per cent.

Effect of Pruning on Total Yield

This work corroborates previous work along the same line in that the yield was reduced in proportion to the severity of the pruning given. The difference is very slight between the one and two stem treatments, being less than 7 per cent.

Summary

As a result of the one years work under the existing conditions, pruning and staking has the following effects:

1. Increased the yield of early fruit.
2. Increased the yield of fruit for the first four weeks of the bearing period.
3. Increased materially the size of the individual fruit.
4. Decreased total yield in proportion to the severity of the pruning given.

The differences between the pruned lots were not large enough to warrant any except the least expensive treatment, i. e., single stem pruning.

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The Effects of Fruit on Vegetative Growth in Plants

By A. E. MURNEEK, *University of Wisconsin, Madison, Wis.*

THE primary object of this paper is (1) to draw attention to the effects of correlation between fruit and vegetative development in horticultural plants and (2) to present a somewhat new method in physiological studies of nutrition of higher plants. The conclusions reached here have been obtained from an intensive study of growth and yield in the tomato, the detailed results of which will be published elsewhere.

Vegetative growth and reproduction are very generally considered to be two antagonistic functions of plants. Thus excessive vegetative development is thought to be detrimental to either the initiation of flowers, or the proper function of the reproductive organs, while diminished growth is assumed to be the forerunner of a good yield of seeds and fruit. That fruitfulness is frequently associated with comparatively weak growth is but a commonly observed fact. The question, however, is, which in this relationship is cause and which is effect.

Information throwing some light on the subject has been secured by the writer as a result of investigations with the tomato extending over a period of several years. The plants were grown in sand cultures with and without nitrogen. Some were raised in very rich garden compost to which a liberal supply of manure was added from time to time. As a rule, check and treated plants were grown side by side in the same pots, or adjacent to each other in the greenhouse beds.

In every instance the presence of a relatively large crop of fruit was found to be the cause of retarded vegetative development. This was true under all and very extreme planes of nutrition as regards nitrogen supply. Thus plants extremely low in nitrogen were completely inhibited in further growth by a single small fruit. The terminal growing point was often completely destroyed and disappeared, the fruit becoming "tip" as it were. A timely removal of the fruit resulted in a complete recovery of vegetativeness and a subsequent normal growth a foot or more in length. On this new portion of the stem flowers again were produced, which, when fertilized, set fruit once more.

A similar situation, only on a greater scale and hence more conspicuous, was exhibited by nitrogen high plants. These, however, required the presence of several large fruits, in extremely vegetative specimens as many as 30, before complete cessation of further vegetative development was brought about. When the fruit was removed from such plants a really extraordinary development took place. For all it appeared as if these plants were starting life all over again. Frequently they attained a size twice or three times that of the check plants growing in the same pots.

The inhibitory effects of the fruit on development proceeded in approximately the following sequence: (1) Destruction of fecundity of the flowers. Though pollination was practiced regularly, the blossoms could not be induced to set fruit. (2) Decrease in size of the flower clusters and all floral organs. (3) Yellowing and abortion of flower buds. (4) Decrease and cessation of further elongation of the stem, and (5) complete exhaustion and eventual death of all parts of the plant excepting the fruit.

One can readily recognize that these are but the unmistakable signs of nitrogen starvation of increasing intensity. This is particularly interesting in view of the fact that in many instances an ample and even excessive supply of nitrogen was provided for the plants, as was shown by the rapid recovery and the tremenduous growth following the cutting of fruit. Apparently the fruit is able to draw and monopolize in some way practically all of the incoming and synthesized nitrogenous substances, to the detrimental effect on other parts of the plant.

Evidence from chemical analyses tends to support this view. A surprising "chemical stability" was shown by the fruit under all conditions of nutrition. Whether the nitrate content of the plant as a whole was high or low, practically no nitrates were found in the fruit, but instead relatively large amounts of insoluble and soluble nitrogen of various kinds. So, too, the percentage composition of total nitrogen was always higher in the fruit than any other part. To be sure, the fruit showed also very high percentages in all forms of carbohydrates, particularly starch and reducing sugars. But these being found in large quantities elsewhere in the plant, carbohydrates do not appear to have operated as the immediate limiting factors. Under certain conditions, however, this might happen. When, for instance, tomato plants are grown with a short daily exposure to light, or under conditions of low light intensity and comparatively high temperature, carbohydrate synthesis may be reduced to such an extent that a shortage may ensue, leading, like a shortage in nitrogen supply to inhibition in development. Such a solution presenting itself the morphological behavior of the plant may be interpreted on the basis of a relationship between carbohydrates and nitrogen. It is of particular interest to note here that the validity of the carbohydrate-nitrogen relation theory asserts itself in this case also.

The foregoing information points to the fact that in all studies of nutrition of seed plants the rôle of the fruit in the adjustment of a plant to its external and internal environment should receive the proper emphasis. The morphological expression of the development of a plant is determined not only by its genetic constitution and the nature and intensity of environmental factors, but likewise by the effects of correlation of its organs. Hence in many instances experimental treatment of the reproductive parts of the plant and observation of the resultant response in both vegetation and reproduction would most likely be of the greatest value. It is quite clear that in many horticultural plants, particularly perennials, the vegetative growth

in any particular season is but a prerequisite insurance or indicator, of a future crop.

A rather close examination of the behavior of a large variety of plants leads one to suspect that what is true in the tomato may alse be true in many other plants. A relatively large crop of fruit seems frequently to be the primary cause of a retarded or inhibited vegetativeness. In this respect plants may be roughly grouped into annuals with determinate and annuals with indeterminate growth, biennials, and perennials with indeterminate growth. To the first group belong practically all of the cereals, grasses, etc. In these increase in size of plant usually terminates at the time of fertilization or soon thereafter. The event has a strictly seasonal aspect. Moreover, the relation of vegetative growth to fruiting is comparatively simple. Beside the tomato and the cotton plant, many of the legumes and members of the gourd family may be cited as examples with an indeterminate type of growth. In these plants further extension of the stem is not inhibited at the time of setting of the first fruit, but it usually follows when a maximum crop is attained. Under our climatic conditions biennials, of course, flower and fruit during the second year, at which time growth also terminates. If not permitted to form blossoms, they may live, however, for several years, death commonly ensuing in the year of seed formation. Almost all of the perennials of horticultural importance to us show a condition of indeterminate, but strictly seasonal growth. In this group of plants setting of fruit may precede (citrus), may be simultaneous with (apples, pears), or may follow (cherries, plums) the usual seasonal vegetative extension.

In this respect the woody perennials present a somewhat difficult situation for analysis, which is made the more complex by the presence of proportionally large amounts of storage products of diverse type. Hence they require a special study. Naturally one would expect that in all cases where the reserve supply of nitrogen in the tree is rather low the presence of a large yield of fruit would tend to a marked inhibition in growth. On the other hand the reserves may be ample enough for the development of a large crop and at the same time insure good growth. One can even formulate a condition where under very favorable environmental circumstances during the year of fruiting, vegetative extension may be even greater than in a non-fruiting or off-year. This however, in no way minimizes the decided controlling influence of the fruit on the available food supply of the plant, the effects of which will be the more telling the greater the shortage.

The foregoing discussion should emphasize the necessity of an especially careful study of each group of plants. Moreover, it should indicate the fact that one must refrain from a too sweeping generalization. To the writer the subject seems to be important enough to warrant a most thorough investigation with many other horticultual plants beside the tomato.

Effects of Organic Matter in Maintaining Soil Fertility for Truck Crop Production

By T. C. JOHNSON, *Virginia Truck Experiment Station, Norfolk, Va.*

IN 1908, a series of experiments was undertaken to determine, among other things, the feasibility of substituting certain green crops in the rotation followed in Eastern Virginia, in ieu of large quantities of stable manure for the maintenance of productivity and organic matter in soils used for truck crop production.

A tract of land was selected for this work which had not been under cultivation for a number of years and was in a rather low state of fertility. The vegetation that grew on it in the summer was usually burned off in early winter in order to prevent the growth of pine and other forest trees. It was classified by the Bureau of Soils, U. S. Department of Agriculture, as Norfolk gravelly loam. The surface soil, to a depth of about six inches, varies from gray to a yellowish brown in color. This is underlain by a sub-soil of coarse gravelly loam to a depth of about 24 inches and this in turn with a yellowish sandy loam to a depth of about 36 inches. This type of soil is used quite generally for farm crops and when liberally supplied with fertilizing material and organic matter is used for the production of such truck crops as potatoes, cabbage, tomatoes, spinach, beans and cucumbers.

It is the intention in this discussion to deal only with that portion of the experiment pertaining to crop yields as influenced by the use of stable manure and cover crops turned under. For this purpose the field was divided into three parallel blocks, the first of which received an annual application of 15 tons of stable manure per acre during the course of the work; on the second, eight crops of crimson clover, which were grown in rotation with truck crops, were turned under, but no stable manure was used, and on the third block the rotation was so arranged as to grow crops continuously, without the addition of stable manure and no crop residue was added to this land except the roots of such plants as were left in the ground after the truck crops were harvested. The three parallel blocks were subdivided into plats, extending across all three, which were treated with various fertilizer combinations. One-half of blocks one and two were given five applications of 1,500 pounds of hydrated lime per acre, during the course of the experiment, but the non-humus block received no lime. The data secured from the limed portions of the blocks are not discussed in this paper.

Plat one, received annually 4,000 pounds[1] of commercial fertilizer, analyzing 4 per cent nitrogen, 6 per cent phosphoric acid, and 8 per cent potash. Plat 2, received 2,000 pounds[2] of commercial

[1]Average of plats B 73 and B 74.
[2]Average of plats B 75 and B 76.

fertilizer of the same analysis. The yields from plat three, as here recorded were obtained by averaging the yields of various sub-plats[3] in the experiment which received incomplete fertilizers. The results in plat four were obtained by averaging the yields from six sub-plats[4] which received no commercial fertilizer.

We will here consider briefly the average yields of three crops of Irish potatoes, three crops of sweet potatoes, two crops of kale, and three crops of cabbage obtained on these plats.

Table I gives the average yields of the three crops of Irish potatoes. It will be seen that where 4,000 pounds of commercial fertilizers were used in addition to stable manure, an average yield of 226.2 bushels per acre was obtained, and where green manure crops were turned under, the yield was 224.2 bushels, and where the same amount of commercial fertilizer was used without any organic matter having been applied, 138.8 bushels were obtained. Compared with the yields from the non-humus plats, the use of stable manure increased the yields of potatoes 62.9 per cent, and the use of cover crops gave an increase of 61.5 per cent, which was practically the same. Where 2,000 pounds of commercial fertilizer was used, the yield of potatoes was only 199.8 bushels with the addition of stable manure, and with the addition of cover crops it was 232.1 bushels as compared to 155.1 bushels from the non-humus plats. In this case,

TABLE I.

Average Potato Yields for the Years 1916, 1918, 1920

	Yield in Bushels per Acre		
	Stable Manure	Green Manure	Non-Humus Treatment
Complete fertilizer, 4000 pounds per acre...	226.2	224.2	138.8
Increase over non-humus treatment, per cent	62.9	61.5	—
Complete fertilizer, 2000 pounds per acre...	199.8	232.1	155.1
Increase over non-humus treatment, per cent	28.8	49.7	—
Incomplete fertilizer....................	134.5	71.0	39.7
Increase over non-humus treatment, per cent	238.8	78.8	—
No fertilizer..........................	82.4	30.9	19.2
Increase over non-humus treatment, per cent	429.2	60.9	—

the yield from cover crop treatment is superior to that from the stable manure treatment. This may be due, in part at least, to the large amount of nitrogen furnished by the leguminous cover crop. The increases over the non-humus treatment were 28.8 per cent and 49.7 per cent for the stable manure and the cover crop respectively.

[3]Average of plats B 80, 81, 82, 45, 89, 43, 79.
" " " C 73, 75, 82, 83, 84, 85, 87.
76, 77, 79, 80, 81.

[4]Average of plats B 77, B 92.
" " " C 86, 90, 91, 92.

Plat three, in which incomplete fertilizer was used, gave an average yield of 134.5 bushels with the stable manure, 71 bushels with the organic matter turned under, and 39 bushels with the non-humus treatment. On plat four, where no fertilizers were used, the stable manure gave an average yield of 82.4 bushels, and the cover crop turned under, a yield of 30.9 bushels as compared to 19.2 on the non-humus plat.

Table II, gives the yields obtained from sweet potatoes in this test. The use of stable manure with 4,000 pounds of commercial fertilizer increased the yield of sweet potatoes only 18.5 per cent, while the green crops turned under gave an increase of 7.5 per cent over that obtained from the non-humus plats. Again, where 2,000 pounds of commercial fertilizer were used the stable manure increased the yields of sweet potatoes 19.3 per cent, and that the green crops apparently reduced the yield 7.8 per cent. The check plat which received no commercial fertilizers gave a heavy yield with the stable manure and a medium yield with the organic matter turned under. On the check plat on which no fertilizers were used, the stable manure gave an increase of 116.6 per cent, and the organic matter turned under an increase of 21.9 per cent, over the check plat which received neither humus or commercial fertilizers.

TABLE II.

Average Sweet Potato Yields for the Years 1917, 1919, 1921

	Yield in Bushels per acre		
	Stable Manure	Green Manure	Non-Humus Treatment
Complete fertilizer, 4000 pounds per acre...	250.2	227.0	211.2
Increase over non-humus treatment, per cent	18.5	7.5	—
Complete fertilizer, 2000 pounds per acre...	316.5	244.5	265.2
Increase over non-humus treatment, per cent	19.3	7.8	—
Incomplete fertilizer....................	294.9	223.7	175.1
Increase over non-humus treatment, per cent	68.4	27.7	—
No commercial fertilizer..................	260.8	146.2	119.9
Increase over non-humus treatment, per cent	116.6	21.9	—

In Table III, the yields of kale are expressed in barrels per acre. The stable manure with the 4,000 pounds of commercial fertilizer increased the yield 87.5 per cent, and the organic matter increased the yield 32.5 per cent, over the non-humus plat, but with the 2,000 pounds of commercial fertilizer, the stable manure increased the yield only 26 per cent and the organic matter increased the yield only 9.2 per cent. The beneficial results from the use of stable manure or green manure with a complete fertilizer with kale, were not as marked as when used in connection with the potato crop.

On plat three, in which incomplete fertilizer was used the yield on the non-humus plat was very low, while a fair yield was obtained

with both manure and cover crops, and on the check plat the stable manure gave a satisfactory yield, while the green manure and the non-humus plat gave very low yields.

TABLE III.

Average Kale Yields for the Years 1912 and 1913

	Yield in Barrels per Acre		
	Stable Manure	Green Manure	Non-Humus Treatment
Complete fertilizer, 4000 pounds per acre...	400.3	282.8	213.5
Increase over non-humus treatment, per cent	87.5	32.5	—
Complete fertilizer, 2000 pounds per acre...	386.3	335.2	306.8
Increase over non-humus treatment, per cent	26.0	9.2	—
Incomplete fertilizer..................	265.3	178.8	106.0
Increase over non-humus treatment, per cent	150.3	68.7	—
No commercial fertilizer................	224.4	46.4	23.3
Increase over non-humus treatment, per cent	863.1	99.1	—

With cabbage the stable manure gave an increase of 109 per cent and the green manure 64.6 per cent over the non-humus plats where 4,000 pounds of fertilizer were applied, and on plat two, on which 2,000 pounds of commercial fertilizer were used, the increases were 35.7 per cent and 31.3 per cent, respectively. The yields of cabbage on the stable manure and on the green manure plats were unsatisfactory with both the incomplete fertilizers and with no fertilizers.

TABLE IV.

Average Cabbage Yields for the Years 1913, 1914, 1915

	Yield in Crates per Acre		
	Stable Manure	Green Manure	Non-Humus Treatment
Complete fertilizer, 4000 pounds per acre...	157.6	124.1	75.4
Increase over non-humus treatment, per cent	109.0	64.6	—
Complete fertilizer, 2000 pounds per acre...	137.5	133.1	101.3
Increase over non-humus treatment, per cent	35.7	31.3	—
Incomplete fertilizer..................	92.1	54.3	23.9
Increase over non-humus treatment, per cent	285.3	127.2	—
No commercial fertilizer................	61.7	11.9	4.5
Increase over non-humus treatment, per cent	1271.2	164.4	—

Conclusions

From the foregoing it will be seen that both potatoes and cabbage responded exceptionally well to the use of organic matter, either in the form of stable manure or green cover crops turned under, especially when used in combination with a complete commercial fertilizer; but that when incomplete fertilizers are used, the yields of both of these crops were materially reduced, even in the presence of large quantities of organic matter. In the case of cabbage the use of stable manure with complete fertilizer gave slightly better results than green manure, but in case of potatoes, the advantage is with the green manure.

In the production of kale and sweet potatoes, very satisfactory yields were obtained by the use of a complete commercial fertilizer without the addition of humus. The influence of stable manure and organic matter was decidedly less marked than when used on potatoes and cabbage.

In the production of potatoes, kale and cabbage, the beneficial effect of organic matter from green manural crops with an incomplete fertilizer is less than when used with a complete fertilizer, because of the unbalanced ratio of the essential plantfood elements. Where no commercial plantfood was applied the green manural crop made slow growth, added very little organic matter to the soil and did not materially increase crop yields.

Some Unusual Results in Fertilizing Fruit Plants

By J. K. Shaw, *Massachusetts Experiment Station, Amherst, Mass.*

In the year 1889, there were started at various experiment stations a considerable number of what were called soil test fields. These fields were to have a fixed fertilizer program and were to be planted from year to year with various farm or garden crops. The purpose was to find out the fertilizer needs of the various soils tested. Perhaps the most important result of these tests has been to show that the fertilizer need of the crop is the important thing rather than that of the soil. It has been clear that different crops have responded differently to these fixed fertilizer programs. So far as the writer's knowledge goes no fruit crops have been used on any of these soil test fields.

Two of these soil tests were established at this Experiment Station in 1889, and for about 30 years were maintained with fixed annual fertilizer applications and various field and garden crops grown.. In the spring of 1922, one of these fields was planted to apples, peaches, grapes and currants. The following year the currants were removed and Columbian raspberries substituted. The field contains 13 plots, four of which have had no fertilizer applications during the

entire period. The materials used alone and in combination are nitrate of soda 160 pounds per acre, dissolved bone black 320 pounds per acre, and muriate of potash 160 pounds per acre. When the fruit plants were set an equivalent amount of acid phosphate was substituted for the bone black. One plot has had land plaster 160 pounds per acre, later increased to 400 pounds and since 1902, 800 pounds per acre. One plot has had 160 pounds dried blood per acre in addition to the standard amounts of mineral fertilizers, but as this plot has had a somewhat different history it is not here considered further than to say that results have been similar to the other complete fertilizer plot.

The plots are 10 feet wide and 120 feet long and are separated by an unfertilized strip three feet wide. One-half of the field across the plots has been limed from time to time, last in 1916, the total amount in four applications being 4½ tons per acre.

The field lies on a gentle western slope and the soil is classified by the Bureau of Soils as the Merrimac coarse sandy loam. Despite the rather coarse texture of the soil it seems quite well supplied with water though never in excess and it is doubtful if the trees have suffered materially from a surplus or deficiency of water. The soil management has been on the cultivation cover crop system.

The peach and apple trees alternate and are 10 feet apart on the plots; they are interplanted with grapes and raspberries alternately. There are on each plot 10 plants of each fruit, five being on the limed portion and five on the unlimed portion.

The results obtained during the first 30 years of this test with various crops have been reported from time to time in the publications of this Station and are finally summarized in Bulletin 212 by Director Haskell published in 1922. The field has generally shown a rather marked response to potash especially when certain "potash hungry" crops were grown.

Of course there has been no expectation of developing a real orchard with such close planting, but it was thought that in view of the long continued fertilizer program on the several plots some interesting responses on the part of the trees might be obtained.

No differences between the plots could be observed until about July 15 when the plots not receiving potash showed more or less bronzing of the leaves. This has since been observed on other plots, but increasing differences in the growth of the trees and vines have since appeared.

The amount of growth on the different plots has been compared by measuring the length of new wood produced each year. These measurements are summarized in Table I.

A study of this table shows that the peach trees have the most marked and significant differences of any of the three fruits. And yet here the only increases in growth apparently due to fertilizer that can be said to be significant are on the plots receiving potash. The nitrogen and nitrogen-phosphorus plots that might be expected to show results are no better if as good as the check plots that have received no fertilizer applications for at least 35 years.

It is of further interest to note that the striking increases of growth are on the limed portions of the potash plots. Increases on the unlimed potash plots are of somewhat doubtful significance. On the other hand the no potash plots show a tendency in the opposite direction, the limed portions are on the whole inferior to the unlimed.

TABLE I.

Average Total Shoot Growth in Feet

	Peach		Apple		Grape
	1922	1923	1922	1923	1922 & 1923
1. Check Not Limed	19	93	5.8	14.7	21.7
" Limed	12	76	2.3	16.1	8.3
2. Nitrogen Not Limed	22	110	2.1	9.4	17.3
" Limed	15	86	1.9	10.0	8.7
3. Phosphorus Not Limed	15	68	1.0	8.0	11.7
" Limed	15	70	1.6	10.8	9.4
4. Check Not Limed	20	97	3.4	14.0	22.2
" Limed	18	105	1.8	12.1	18.4
5. Potash Not Limed	17	134	2.8	10.7	15.4
" Limed	24	199	5.8	9.8	22.7
6. Nitrogen and Phosphorus Not Limed	22	93	3.0	11.8	18.0
Nitrogen and Phosphorus Limed	17	48	2.3	15.7	15.2
7. Nitrogen and Potash Not Limed	25	95	2.6	7.7	12.3
" " " Limed	31	164	3.3	13.7	16.0
8. Check Not Limed	8	50	1.8	16.7	14.4
" Limed	21	104	1.7	15.4	8.6
9. Phosphorus and Potash Not Limed	19	112	3.6	11.9	10.6
" " " Limed	35	251	8.7	32.3	22.5
10. Nitrogen, Potash and Phosphorus Not Limed	20	96	4.6	12.5	17.6
Nitrogen, Potash and Phosphorus Limed	39	167	8.5	20.0	24.9
11. Land Plaster Not Limed	11	80	1.7	4.3	14.9
" " Limed	17	60	.5	10.7	7.2
12. Check Not Limed	13	51	3.5	12.7	21.1
" Limed	10	41	1.3	12.5	13.9

In regard to the growth of the apple trees there are few if any differences in growth that can be attributed positively to the fertilizers used. The limed portion of the complete fertilizer plot shows considerably greater growth than other plots and the limed portion of the phosphorus-potash plot is strikingly greater than any others.

There is little or no evidence that the added nitrogen has helped the trees at all, and phosphorus alone is harmful rather than beneficial and of doubtful value when added to the other elements.

What has been said about the apple and peach trees applies quite generally to the grape vines. In all plots receiving potash the limed portion is better and in all cases where potash is not used including the checks the reverse is true. Phosphorus and land plaster have been harmful rather than helpful. In general the increased growth of any of the fertilized plots over the checks is of doubtful significance.

The cover crops grown in this orchard for the past two years have been a mixture of rye and buckwheat and it has been interesting to observe the behavior of these crops on the same plots for it has been quite unlike that of the fruit plants. Notes on cover crop growth are summarized in Table II.

TABLE II.

Growth of Cover Crops

Plot	Rye		Buckwheat	
	Limed	Unlimed	Limed	Unlimed
1. Check	Medium	Medium	Good	Medium
2. Nitrogen	Medium	Good	Good	Medium
3. Phosphorus	Medium	Medium	Medium	Good
4. Check	Medium	Medium	Good	Medium
5. Potash	Good	Medium	Good	Medium
6. Nitrogen-phosphorus	Very good	Very good	Very good	Very good
7. Nitrogen-potash	Very good	Medium	Good	Poor
8. Check	Medium	Medium	Good	Very poor
9. Phosphorus-potash	Good	Good	Medium	Poor
10. Complete fertilizer	Very good	Very good	Good	Very good
11. Land plaster	Medium	Poor	Medium	Medium
12. Check	Good	Poor	Very good	Very poor

As might be expected rye has been on the whole indifferent to lime though on the potash plot it has grown better on the limed portion. It has grown far the best on the nitrogen-phosphorous and complete fertilizer plots, and there has been little difference between these two. On the phosphorus-potash plot the growth has been a little better, but on the other fertilized plots it has grown little if any better than on the checks.

Buckwheat has shown marked differences, making a very good growth on some plots and being practically a failure on others. It has grown better on the limed portion of all the check plots and on most of the fertilized plots and strikingly so where potash is used. Where nitrogen is used the unlimed portion of the plots have shown as good growth of buckwheat as the limed portion except on the nitro-

gen-potash plot where the limed portion is better. Growth on the nitrogen-phosphorus plot has been equal to that on the complete fertilizer plot. There has been little difference between the limed and unlimed portions of these two plots.

The peach trees have produced only a few scattered fruits, but in the spring of 1923 there was found to be a considerable number of fruit buds on the shoots, some alive and some winter killed. Approximately equal lengths of shoot growth (about 10 feet per tree) were cut, and counts made of the numbers of live and dead fruit buds. These figures are deemed hardly worth presenting in detail. The highest number of fruit buds was found on the limed portion of the complete fertilizer plot where 39 per cent of the nodes bore fruit buds. The lowest only two per cent was on the limed portion of check plot 8. In general the number of buds per foot of growth was proportional to the amount of growth, the more growth the more fruit buds per foot of growth. About three-fourths of the fruit buds were alive and no relation between the fertilizer treatment and the proportion of killed buds could be detected.

Determination of the hydrogen-ion concentration on six of the plots were made on August 29, 1924. The Ph values on the limed portions did not vary greatly, being 6.6 on the phosphorus potash plot, 6.8 on the phosphorus, check plot four and potash plots, and 7.0 on the nitrogen and nitrogen-potash plots. On the unlimed portions of these plots differences were somewhat greater varying from 5.2 on the phosphorus-potash plot to 6.4 on the potash plot. On the other plots the Ph values were as follows, check plot four, 5.4; nitrogen plot 5.6; phosphorus plot 6.0; nitrogen-potash plot 6.2.

Discussion

One must exercise caution in drawing conclusions from this experiment at this time. The number of plants is small and the length of time it has continued is short. It seems quite clear that the potash treatment is the one to which the trees have responded most distinctly. There can be no doubt that there is a real response of the trees to potash and little doubt that the trees on the limed part of the potash plots have responded with better growth. No positive conclusion is offered as to why this is true.

The growth of the trees on the check plots which have had no fertilizers for 35 years is rather remarkable. The trees are still small and it is doubtless true that the roots have not yet exploited all the available soil. They may still extend into fresh soil each season. Evidently the soil still contains enough nutrients for a fair growth of the trees.

There can be no question that most orchards on New England soils, even under cultivation will after a few years respond to applications of nitrogen if not to other fertilizers. Yet in this case the nitrogen or nitrogen-phosphorus plots show no better growth than the checks nor does the complete fertilizer plot show distinctly better growth than the phosphorus-potash plot. In another paper to be

presented later at this meeting another experiment giving different results will be presented and some further comments on this nitrogen response will be given.

The present report is one of progress. The experiment has thus far been more valuable in raising rather than solving problems. It is our purpose to attempt progress in the solution of these problems in the next few years.

Determination of the total nitrogen in the shoots of the trees from the several plots both limed and unlimed showed it to be lowest on the plots making the best growth and the highest on the plots making poorest growth. Thus the two highest total nitrogen contents were found in trees on the limed portions of the land plaster plot, 1.46 per cent and the nitrogen-phosphorus plot 1.43 and the two lowest on the limed portions of the complete fertilizer plot 1.06 per cent and the phosphorus-potash plot 1.12 per cent.

This may indicate that where some condition for growth other than a plentiful supply of nitrogen is wanting, nitrogen is absorbed in excess and remains in the tissues, but when all conditions for growth are favorable, growth takes place and the nitrogen is distributed through a greater amount of tissue but in smaller relative amounts.

The Relation of Maturity to Jonathan Breakdown

By P. M. Daly, *Central Experimental Farm, Ottawa, Canada*

JONATHAN breakdown, or "flesh collapse," has appeared in the Okanagan Valley of British Columbia, more or less in negligible quantities, during the past 16 years. The widespread prevalence of this physiological trouble in 1922, however, was responsible for a loss to the growers there estimated to be well over $350,000.

The Jonathan variety would appear to be physiologically weak and particularly susceptible to such troubles as drought spot and corky core (or brown core) as well as breakdown. According to our own observations and those of Ramsay, McKay, Markell and Bird (7) the Jonathan varies more in keeping qualities than other varieties yet the favor with which the variety meets on local and foreign markets and the fact that nearly 30 per cent of the total plantings in British Columbia are of this variety render necessary the finding of some immediate means of relief to the grower.

Breakdown, or flesh collapse, consists of a premature browning of the flesh of the apple. Examination of the tissue involved in breakdown shows that actual disintegration of the cells and cell walls occurs. In British Columbia Jonathans the areas first browned lie adjacent to and radiate outward from the primary vascular bundles in a manner identical with that found to be the case by Winkler

(10) in Pajaro Valley Yellow Newtowns. The causal factor may be autolysis, enzyme action, unequal osmotic pressure due to the distended condition of the cells which accompanies water core, or it may be due to an accumulation of the essential oils or other deleterious substances. The actual solution of the cause of breakdown is a rather knotty problem, hence the most readily accessible method of attack was sought.

Questionnaires were sent out to over 2000 growers in an endeavor to accumulate as much information as possible regarding the number and date of irrigations applied, nature of soil, amount of soil moisture, fertilizers used, and the amount and conditions under which breakdown occurred. In the 400 replies received, the most valuable fact brought out was the rather general opinion of more intelligent growers that they believed Jonathans were left too long on the trees in order to acquire high color. As a result of this opinion a picking date experiment was carried out in the fall of 1923. The object of the investigation was to find the relation to breakdown of maturity, size of fruit, age and vigor of trees, storage and shipment methods, soil fertility, cultural methods, irrigation practices and climatic and seasonal conditions. Five orchards were selected as fairly representative of the Valley. Twelve trees nine to 18 years old, in each orchard, except Salmon Arm where three only were used, were selected under as varying conditions of soil, moisture, cultural methods and vigor as possible. Careful notes on all environmental factors were made; all fruit was examined thoroughly and a representative sample cut open at picking. The identity of the fruit from each tree was maintained throughout the experiment, along with the date of each picking. Except for Vernon and Salmon Arm, the former being picked in duplicate lots and the latter in single lots, pickings were made in quadruplicate, one lot going into well ventilated storage at the Summerland Station, another into a non-ventilated cellar at the same place, and two lots stored at Kelowna, one of which was shipped to Ottawa November 5 and the other December 19. Well colored and under-colored, small and large fruit was picked alike in each lot. Picking was carried on twice weekly from September 17 until October 27, thus commencing in advance of the commercial practice and extending beyond the date when it had generally been concluded. The storage used at Kelowna was of the ordinary air-cooled type, in which the temperature ranged from 40 to 60°F., since there is no cold storage used in the Okanagan. The relative humidity ranged from 71 to 88 and according to the thermographed record in transit, except for an appreciable rise while the fruit was on the lake boat, it underwent no extremes en route to Ottawa. At Ottawa air-cooled storage again was used and a temperature of 38 to 40°F. maintained throughout the storage period. Optimum conditions prevailed at Summerland in the ventilated cellar, while the non-ventilated storage received no ventilation whatever. The number of boxes picked totaled 186, of which 98 were shipped to Ottawa and the remainder stored and later examined at Summerland.

Examination of the main lot was made at Ottawa November 21

to 28, December 17 to 24, January 16 to 28 and February 22 to 27, while the second check lot was examined January 16 to 28 and February 22 to 27. The fruit was cut open, the condition recorded and particular note made of flavor and texture of the earlier pickings. Nine thousand three hundred and sixty apples were examined and from these the data given are compiled. Of the 51 trees used in the experiment 38 bore fruit which broke down during the latter pickings, and of these 38 trees 26 bore fruit which broke down in appreciable quantities. In detail, 10 of 12 at Kelowna, 11 of 12 at Vernon, seven of 12 at Okanagan Centre, seven of 12 at Summerland, and at Salmon Arm all three trees bore fruit breaking down in the later pickings.

Fruit picked prior to October 11 showed only one apple breaking down of 5460 examined. In the fruit picked October 11 to 13 but 13 apples of 780 broke down, not an appreciable quantity, but fruit picked after that date showed in every case a considerable percentage of breakdown.

Of the fruit found to break down only a relatively small proportion was other than the larger sized and higher colored apples. This observation is in agreement with the findings of Hartman (2), Winkler (10), and Ballard, Magness and Hawkins (1). Some observations made this year on late picked Okanagan Jonathans showed 34 per cent breakdown in 125's as against 10 per cent in 138's and appreciably less in smaller sizes, hence the fact that it is the larger well colored fruit which breaks down would seem to be fairly well established.

As regards the amount of breakdown found, this quantity was found to increase from 5.3 per cent for fruit picked October 15 to 17 to 16.6 per cent for fruit picked October 25 to 27 when examined in November. Fruit of the same picking dates showed a relatively greater increase at the later examinations, namely, in December 12 to 34.6 per cent, in January 12.6 to 43.3 per cent, and in February 17.3 to 48.0 per cent. The average percentage breakdown for the last four pickings showed a similar increase as the storage period advanced, in November 10.6, in December 21.8, in January 26.5 and in February 29.6. This increase in the quantity of breakdown developing as the storage period advances was found to be the case by Hartman (2), Stubenrauch (8) and Waters (9).

Both main lot and check shipment showed this increase, as did similarly the record by individual trees and by orchards with one exception, Okanagan Centre, hence it would appear that where late picking has been carried out immediate shipment to point of consumption in bulk would seem to be the best practices rather than to pick and store fruit which will only decrease in commercial value.

There would not seem to be any particular advantage in holding at point of production over shipping at an earlier date from a comparison of the records of the two lots shipped to Ottawa November 5 and December 19.

An analysis of the varied environmental factors under which the fruit was grown did not reveal any particular condition or set of

conditions which seemed to influence the occurrence or lack of breakdown. It would seem to be quite apparent, however, since Summerland fruit which was picked from trees in many cases devitalized and which showed considerably corky core and drought spot, that the presence of these troubles inhibits the occurrence of breakdown. Fruit from Salmon Arm, a non-irrigated section, showed as much breakdown as did that from twice irrigated and frequently irrigated trees. At Vernon several of the trees were in a block receiving a good application of barnyard manure, several received lime application and the remainder were untreated, yet there was little, if any, difference in the percentage of breakdown found in later pickings. This finding coincides with the work of Ballard, Magness and Hawkins (1), in which they found fertilizers ineffective in controlling breakdown. The theory that lack of lime caused the trouble would not seem to be borne out by these findings. The fact that deciduous fruits are markedly acid tolerant provides further evidence against such a theory. Of the three trees at Salmon Arm, all of which bore fruit breaking down in 1923, only two bore fruit which broke down in 1922, similar to findings in the Pajaro Valley Yellow Newtowns. Adjacent trees under identical conditions and trees under widely differing conditions showed sometimes little and sometimes a wide difference in the amount of breakdown.

The impression that seasonal conditions are partly responsible for the amount of breakdown seems to be founded on fact in 1922 insofar as maturity is affected by and related to the climatic conditions. The season of 1922 was an exceptionally dry one, in comparison with the records of other years, the precipitation was not a third of 1923, while the hours of sunshine were materially greater. Hence, while picking of Jonathans was carried on at the normal time in 1922, the date of maturity was apparently considerably earlier that year.

The fruit stored at Summerland is reported by Palmer (6) to show that by December 1 four times as much breakdown had occurred in the non-ventilated storage as in that ventilated every night, but by January 1 the amount in ventilated and non-ventilated had reached a level where there was practically no difference between the fruit stored in the two cellars. It was also found that there was practically no increase after January 1 in the amount of breakdown, whereas the same fruit stored at Ottawa maintained a consistent increase after that date.

Since throughout the experiment temperatures of 38 to 40°F., and in some cases higher, were maintained, conditions prevailing and the results secured more closely parallel those obtained by Hartman than they do the Pajaro Valley experiments where lower temperatures increased the quantity of breakdown. However, the writer is inclined to disagree with Kidd and West (3) and (4), who state that it is a cold storage trouble and not so much a difficulty with ordinary storage.

In the work done in the Okanagan there appeared to be but little influence exerted by locality and this fact that locality is apparently

relatively insignificant, as far as the cause of the disease is concerned, coincides with Waters' (9) conclusions.

According to Kidd and West (3) and (4) immature fruit also showed breakdown, but, though considerable immature fruit was picked in the course of the experiment, not the slightest trace of breakdown was discovered and the only effect encountered was that of shrivelling, lack of color and flavor, as reported by Ramsey, McKay, Markell and Bird (7) in the Jonathan.

Ballard, Magness and Hawkins (1) observed that in 1919-20, a year when there was a large crop, there were only traces of breakdown, whereas in 1920-21, with a much lighter crop, it was far more prevalent. In the Okanagan, the year 1922, when the greatest loss of recent years was met with, was not a heavy Jonathan crop year, whereas in 1923, when there was a heavy crop of the variety, the occurrence of breakdown was confined to negligible quantities. But in the experiment carried on trees both heavily laden with fruit and with but a sparse crop produced fruit breaking down in the later pickings.

Because of the wide variations in cultural methods, vigor, water supplied, etc., without corresponding differences in the quantity of breakdown, to date no definite conclusion regarding the effect of these conditions is possible. The primary and outstanding conclusion possible is that maturity is one of the most important, if not the most important factor in the Okanagan. There would seem to be a critical point before which picking must be completed and in such a season as 1923 this critical point apparently was reached on October 10. These experiments are being continued this year and probably next to determine more definitely the date after which picking of Jonathans is unsafe over a period of years. Support of the relation of maturity to breakdown, however, is not lacking since Winkler (10), Hartman (2), and Waters (9) all found the stage of maturity to have a direct bearing on the amount of breakdown developing in storage.

Such observations as may be made regarding seed color and ground color (probably one of the best indications and one which, according to Magness and Diehl (5), is independent of light exposure), should determine the picking date for Jonathans. It was also found in the Okanagan that the primary vascular bundles turn to a yellow or brown color in many cases and, while not an infallible indicator, since all fruit exhibiting this characteristic did not break down, it may be of value as an additional guide to maturity.

A condition perhaps more intimately associated with breakdown was observed, however, in what, for want of a better name, might be termed radial water core. This consists of clearly defined small water soaked areas radiating in all cases from the primary vascular bundles. When this condition appears if picking were delayed but a few days breakdown was found occurring. At the earliest date of appearance this condition became apparent only a few days, not more than four or five at the most, prior to the date of picking, at which fruit would later break down. Hence the appear-

ance of radial water core was found to bear a significant relation to breakdown and may prove in the Okanagan to be the best indicator of that stage of maturity which must be avoided. This conclusion regarding the appearance of this type of water core is considerably strengthened by Ramsey, McKay, Markell and Bird (7), who found water core to be largely responsible for the occurrence of physiological decay.

Further work remains to be done in regard to the relation between radial water core, browning of the bundles, and breakdown, but the existence of a definite relationship has at least been established. Continuation of these picking date experiments will furnish further data on the critical stage of maturity which results in breakdown, since the date found for 1923 to be October 10 will be seen to be but arbitrary and must vary with the season. However, a close observation of the maturity of Jonathans in the Okanagan would seem to be warranted and would seem to furnish the means by which losses through breakdown can be reduced to a negligible factor.

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Two Seasons' Work with Fire Blight on Apples*

By R. J. BARNETT, *Experiment Station, Manhatten, Kansas.*

THE Kansas Agricultural Experiment Station apple orchard comprises about 30 acres, the trees varying in age from one to 12 years. Fifty-seven varieties of apples are represented in the orchard. The number of trees of each variety varies from one to as many as 300.

It had appeared desirable to prune parts of this orchard rather heavily during the two years prior to 1923 in order to remove interfering framework branches. This, combined with soil improvement work and the exceptionally favorable weather of June, 1923 caused a rapid, succulent twig growth, and on certain varieties numerous watersprouts, during the early summer.

Early in June a few twig and spur blight infections could be observed in several parts of the orchard. These were at first overlooked, as they were similar in appearance to broken twigs. But as soon as the real nature of the trouble was recognized a survey of the orchard was made. This showed the fire blight to be present in nearly all parts of the orchard, to be much more prevalent on some varieties than on others, and, within the variety, to have made much greater progress on certain trees than on the average.

Jonathan, for example, proved to be one of the most susceptible varieties and nearly all of the 235 trees of this variety showed some blight. However, four trees, and more especially two, were so severely attacked as to indicate serious injury and possible death. These were large, vigorous 10 year old trees. Chenango also proved to be a highly susceptible variety, judging by the one tree in the orchard, as was also Maxwell, a comparatively unknown variety. Among the commercial varieties in this orchard, Rome Beauty was second to Jonathan in susceptibilty to fire blight. Blossom blight, however, is less injurious on this variety because limb cankers can be avoided by surgical means.

THE 1923 CAMPAIGN

As soon as indications pointed to a serious outbreak of the blight, steps looking to its control were taken. The first of these was a survey of the orchard to determine the extent of the injury. Next two young men who understood the nature of bacterial infection and the methods of antisepsis were employed and set to work on the diseased trees.

The method of combating the pest adopted was mainly surgical. It consisted of the removal of all diseased parts well below or beyond the infected region. Combined with this was the careful disinfection

*Contribution No. 59 from the Department of Horticulture, Agricultural Experiment Station, Kansas State Agricultural College.

of the tools and the wounds. In case the infection was on a twig, or a long spur, the process was simple, and if it was possible to cut six to ten inches below the lowest point to which the bacteria had advanced, the wound was not disinfected. When any uncertainty existed, both the pruning implement and the wound were disinfected.

Infections on spurs or those which had gained entrance into large branches were much more difficult to handle. If, upon the removal of a spur close up to a branch, the ring of cambium appeared healthy the wound was merely disinfected. If, however, the bacteria had spread down into the cambium of the limb a cut was made just through the bark and following the outline of the lesion. This plate of bark was then removed, the knife disinfected and a second cut parallel with the first, and one-half of an inch to one inch outside of it was made. This ring of healthy bark was then removed. The wound was next disinfected and, soon after, painted over with water glass at the dilution of one part of water to three parts of commercial water glass.

The disinfectant used in the greater part of this work was that most recently recommended by Professor F. C. Reimer of Talent, Oregon. The formula is bichloride of mercury one ounce, mercuric cyanide one ounce, and water four gallons. This was used for both the pruning implements and the wounds. It was applied by means of a swab made of rags tied around the end of a stick. No metal was allowed to come into contact with the supply of disinfectant, which was carried by each workman in a wide-mouthed glass bottle.

The mercuric cyanide could not be obtained in the local market when the control measures were started so 25 per cent commercial formalin was used as an implement disinfectant and 1 to 1000 mercuric bichloride solution for the wounds. It is a real advantage to have a single disinfectant which will serve for both purposes.

The cutting of blight was continued at frequent intervals until about the 6th of August at which time the hot, dry weather had so slowed up the twig growth of the trees as to enable them to resist the bacterium. The greater part of the orchard was gone over six times during this campaign and a number of the more seriously infected trees received several additional visits and treatments.

There were still blighted twigs in the orchard on August 15 and possibly some limb-cankers, but these were not removed until after the healthy leaves had fallen. At that time and during the winter pruning, an attempt was made to remove all infected areas and an examination made of pear and apple trees in near-by orchards in an attempt to determine the foci from which the early infections originated. The sources from which this year's outbreak started could not be found.

The results obtained through the treatment described were studied on August 10. On this date all the blight cuts made on eight trees of the more susceptible varieties were observed. The results of this inspection are found in Table I.

From the table it may be noted that of the 573 treatment wounds studied only 21, or less than four per cent, showed evidence of active

TABLE I

Results of Treatment of Fire Blight (Eight Representative Trees) 1923

Variety and tree number	Twigs treated	Twigs not cured	Percent cured	Limb lesions treated	Limb lesions not cured	Percent cured	Total percent cured	Remarks
1. Maxwell	87	9	89+	45	0	100	93+	Remaining twigs badly rossetted.
2. Maxwell	54	4	92+	14	0	100	94+	Tree in poor condition. Rosette and spindling growths both present.
3. Jonathan	52	2	96+	15	1	93+	95+	A watery growth stimulated.
4. Jonathan	64	2	96+	17	0	100	97+	Tree in fair condition
5. Jonathan	8	0	100	0	0		100	Very mild attack. Tree in good condition.
6. Jonathan	96	2	98	6	0	100	98+	Tree in fair condition.
7. Jonathan	68	0	100	5	0	100	100	Tree in good condition.
8. Chenango	32	0	100	10	1	90	97+	Tree now in good condition.
Totals	461	19	95.9	112	2	98	96+	

PLATE IX This photograph was taken during October 1923, less than four months after the fruit spur and blight canker had been removed. The variety is Wealthy.

cankers at the time of the inspection. The great majority of these secondary infections, 19, were on twig cuts and in many cases a short shoot had grown before the cut end of the twig had died. In these cases it is fully as probable that the blight gained entrance through the new young shoot as that the cut was too high or the tissue was infected from the pruning implement or otherwise at the time the wound was made.

One of the two limb wounds in which the bacterium seemed to have continued growth was almost certainly due to careless work. The other may have enlarged through infection from a fruit spur just above it. This spur was killed at the time of the inspection and the canker around it had reached the edge of the former wound.

The 1924 Campaign

Preparation was made early in the spring of 1924 to combat any recurrence of the disease. Hold-over cankers within the orchard had been removed with care and no San Jose scale could be found, but blight was known to be present in several farm orchards within a one-mile radius of the station orchard. Green apple aphids were controlled by an oil spray and every effort was made to clean the orchard of sucking insects.

In spite of these precautions fire blight appeared on susceptible varieties toward the close of the blooming period. Blossom blight was scarce on most varieties but abundant on late blooming varieties such as Ralls. The former bloomed during a period of cool damp weather but this had changed to favorable conditions for the visits of the bees by the time Ralls and Rome Beauty were in bloom. Although these and other late blooming varieties showed considerably more blossom blight than the earlier blooming varieties, only very few of the lesions caused by the blight bacterium had an opportunity to extend into the branches on which the blighted spurs were situated. This was because of the soil condition, it being unusually dry, and of the surgical campaign which was started as soon as the attack became apparent. Only two or three of these spur infections spread beyond the spur itself, in contrast with 100 or more such invasions in the season of 1923. Surgery cured all of these cases in 1924.

Twig blight appeared soon after twig growth started and the removal of these infections was started June 2. The same routine as that described for the 1923 campaign was followed. By July 8 the outbreak appeared to be over for the season and operations ceased. The whole orchard had been gone over three times, susceptible varieties six or seven times, certain badly infected trees as many as 10 times, and about 275 hours' time used in the work. The expenditure in money was slightly more than $100. No case was found in which the infection continued following the removal of the twig and secondary twig growth was much less common than during 1923.

Since the early twig infections were nearly as numerous as they were in 1923 it would be safe to assume that the foci were as many and as available. Also, the greater ease with which the outbreak was

controlled in 1924 and the increased effectiveness of the surgical work were due to the climatic and soil conditions. These were such as resulted in a slower and less succulent growth, which is assumed to be less favorable for the development of the blight bacterium. Total twig growth in 1924 was only slightly more than one-half as great as in 1923. Drouth during May and part of June was the cause of this decreased growth for 1924.

Protection from the fire blight involves, first of all, the elimination of hold-over cankers. If these are allowed to become active in the spring, insects will carry the bacteria to the naked parts of the other trees, such as the nectaries of the blossoms or to rapidly growing tips, and new infections occur. A knowledge of the method by which an early summer outbreak of blight is caused indicates clearly that united community effort is necessary if the disease is to be fully controlled or eradicated. Hold-over cankers on all the pear and apple trees of the entire neighborhood must be cut out. The pear and apple growers of Oregon and Washington have shown that such control methods, when backed up by adequate legal enactments, are practical and effective. They saved their trees in the face of a most virulent infection such as had ruined the pear orchards of nearly all other parts of the United States.

The planting of resistant or immune varieties and the control of the rate of twig growth are important accessories to surgery in the control of this destructive American orchard disease. Though definite data are lacking, it would appear that insect control, especially that of the aphis, would greatly lessen the spread of the bacterium.

Habits of Growth and Bearing of Apple Varieties as Related to Biennial Bearing

By W. B. Mack, *Pennsylvania State College, State College, Pa.*

IT IS a recognized fact that certain varieties of apples are more prone than others to fall into the biennial bearing habit. It is likewise generally known that certain varieties differ from others in the manner of branching, in the relative growth of spurs and shoots, and in other characteristics of growth habit. It is not known, however, whether there is any relation between the habits of growth and the type of bearing. A knowledge of this, it would seem, might serve to throw some light upon the nutritional conditions concerned with the vexing problem of biennial bearing.

The study reported here is concerned with the relation of habits of growth and bearing in certain varieties of apple ranging in type of bearing from annual to very marked biennial. The chief difficulty in the study was the establishment of measures by which these habits could be expressed quantitatively.

The following measures were finally adopted, for each tree studied:

1. Length of growth of terminals, in one centimeter classes.
2. Length of growth of spurs of various ages, in one centimeter classes.
3. Percentage of bearing and non-bearing growths in the above classes.
4. Percentage of bearing on successively blossoming spurs of various lengths and ages.
5. Percentage of spurs and shoots bearing from axillary buds.
6. Percentage of the total crop on terminals and spurs of various ages.

These records were taken on 25 trees for two successive seasons, 1922 and 1923, and on 21 others for one year only. Some of the latter were studied in 1922 and some in 1923. Other records taken on a number of trees were the percentage of bloom and the percentage of set. Yield records were secured on practically all the trees for the years in which they were studied, and in most cases for a year or two previous to the beginning of the detailed study. In all, detailed studies were made on 46 trees of nine varieties, and measurements and observations were taken on approximately 82,500 growing points.

The biennially bearing varieties studied were Wealthy, Oldenburg, Wagener, Baldwin and York Imperial. These varieties, though they may not be biennial under all conditions, were generally so in the orchards where these studies were made. Some distinctly alternating trees of each variety were selected, and a few cases were found in which alternation was not so marked. Where branch-to-branch alternation was found, studies of the separate branches were made. The annually bearing varieties observed were McIntosh, Ben Davis, Gano, Twenty Ounce and Stayman Winesap. Most of the trees were in the orchards of the Massachusetts Agricultural College; the rest were in the experimental orchards of the Pennsylvania State College.

Comparisons were made of the measurements described above on the same tree in successive seasons, to obtain some idea of the differences accompanying alternation in bearing of the same tree. Since these differences were likely to be affected by seasonal climatic changes, similar comparisons were made of trees under like conditions, alternating with each other in the same season.

The following conclusions were drawn from the observations and comparisons:

1. The growth of all the trees, with very few exceptions, shows a characteristic alternation of spur vigor, as expressed in average length of growth. This is true of both biennial and annual trees. On the biennial varieties, the greater spur vigor is associated with the formation of blossom buds.
2. The vigor of the terminal growths is variable. In some varieties it is greater in years when the spur vigor is less, and vice versa. In other varieties, it is positively correlated

with spur vigor, to a greater or lesser extent. In many cases it seems to be dependent both upon the vigor of the tree and the state of bearing, while in other cases it is dependent mainly upon the state of bearing. Terminal vigor is most often relatively greater in the bearing year of biennial varieties than in the non-bearing year.

The spur vigor of annually bearing varieties is relatively greater than that of biennially bearing varieties. The relative number of spurs of annual varieties is less than that of biennial ones.

3. In biennial varieties, the terminals and young spurs bear more heavily than older spurs in the on-year. In annual varieties where alternation of bearing habit exists, the terminals and young spurs bear least when the older spurs bear most heavily, and vice versa. The lighter crop usually accompanies the heavier bearing of the terminals and young spurs.
4. Annual bearing trees of a variety ordinarily considered to be biennial is brought about by alternation between branches or by successive blossoming of spurs when the set is light in the on-year. It is never brought about by alternating sets of spurs.
5. Bearing on successively blossoming spurs takes place to a very limited extent in biennial varieties; it is quite common in annual varieties. When it occurs it is nearly always associated with a low percentage of set.
6. Biennial varieties form a higher percentage of shoots and a lower percentage of spurs in the on-year than they do in the off-year. If anything occurs to reduce the set to a great extent in the normal on-year, the percentage of shoots formed is usually very high in that year.
7. Ordinarily the biennial tree forms a much higher proportion of spurs, in comparison to the number of terminals, than the annual tree.
8. Non-bearing growths of a bearing tree were less vigorous on the average than the bearing growths, but were evidently not a separate population.
9. In all varieties, second growths from terminals usually form blossom buds. Evidently conditions either within the tree or outside it are uniformly favorable to blossom bud differentiation at the time these growths are completed.
10. Bearing from axillary buds is common in the on-year of biennial varieties, but is otherwise not frequent in occur rence.

Briefly, biennial bearing is associated with:

a. The formation of blossom buds on growths of all lengths in the year of greater spur vigor;
b. The tendency to form a great number of spurs and relatively few shoots, especially in the non-bearing year;

c. A high percentage of set, regardless of the amount of blossoming;
d. A percentage of bearing increasing with length of growth, in the on-year;
e. High vigor of axillary buds, both in bearing fruit and in forming a large number of spurs.

Annual bearing differs in being associated with:

a. The formation of blossom buds mainly on spurs in the year of greater spur vigor, and sometimes, the formation of blossom buds on terminals in the year of lesser spur vigor;
b. The tendency to form fewer spurs, and to make a large individual spur growth;
c. A rather low percentage of set, and as a consequence, considerable successive blossoming on the same spurs;
d. In most cases, the highest percentage of bearing on spurs of medium length;
e. Comparatively low vigor of axillary buds, in that they bear very little fruit, and fewer of them develop into spurs.

There is no indication in the results of this study that the biennial bearing habit can be broken up by the modification of the vigor of the tree. Various methods have been suggested for the accomplishment of this end. One of these is the stimulation of greater terminal growth in the on-year by pruning and fertilization, in the hope that the spur growth at the same time would be greater. Two results of this investigation indicate that this method is likely to be unsuccessful. One of these is the fact that under normal conditions relatively more terminals are formed in the on-year than in the off-year. The other fact is that the growth of the spurs is not very closely correlated with that of the terminals. The effect of the stimulation of more vigorous terminal growth, therefore, would be in the end, the formation of a greater number of spurs in the off-year. This would serve only to emphasize the on-year. In fact, the work of Bradford on the effect of nitrogen upon bearing habit, indicates that this is true, since nitrogen increased not only the total number of spurs, but also the number of spurs on terminals of the same length.

The indication is rather that the means of control of biennial bearing is the reduction of the excessive amount of fruit setting by blossom-thinning or other means before the set has actually occurred, in the on-year of the biennial tree. In the cases where the setting of fruit was reduced by natural causes, annual cropping resulted, though the alternating habit of growth of the trees was not essentially changed.

Another indication is that everything which tends toward heavy yields in biennial varieties likewise tends toward biennial bearing. The stimulation of strong terminal growth, the development of a proportionally great number of spurs, the setting of fruit on axillary and terminal buds of terminals and young spurs, and a high percentage of fruit setting, all of which are associated with heavy bear-

ing, are also associated in every case with marked biennial bearing. It is evident, therefore, that efforts which are properly directed toward heavy bearing of varieties prone to fall into the biennial habit are likely to result also in biennial bearing.

Annual Crops from Biennial Bearing Apple Trees

By B. D. Drain, *Agricultural College, Amherst, Mass.*

ANNUAL crops from biennial bearing apple trees have long been a goal of the fruit grower. We have frequently observed apple trees that produced good crops for a number of years in succession. This may come about by sections of the tree fruiting in alternate years, or by each large branch producing a fair crop each year. The latter is the fruit grower's ideal.

Goff (2) showed that blossom buds of apple began to differentiate by mid-summer. Roberts (4) found a correlation between the amount of growth and blossoming for a given spur. Hooker (3) found marked differences in carbohydrates between bearing and non-bearing spurs during and just following blossoming. Crow (1) showed that there was a "critical period" in blossom bud formation at the time of fruit setting. He also found that the removal of the blossoms from a given spur was often followed by the formation of a blossom bud. This would lead to the conclusion that over setting was at least one of the more important causes of biennial bearing. Fruit setting is used in this manuscript in the sense of fertilization completed, followed or accompanied by more or less growth of the fruit.

The author has been trying out the claims and suggestions of various experiment station workers on this question. Up to the present time, we have not been able economically to maintain apple trees in annual production by pruning, fruit thinning, fertilizing, intensive culture, or by combination of these. The above tests were carried out on Wealthy apple trees about 26 years old that had been forced into annual production by blossom thinning due to low temperatures in 1921. This blossom thinning was fairly uniform over the entire tree and killed the more advanced blossoms.

The accompaning Table is a production record of several of these Wealthy trees.

The 1920 records are included to show what the trees were producing previous to blossom thinning. The 1923 and 1924 records are included to show the extent of time of the blossom thinning effect. Judging from these records, blossom thinning, (before the blossom is fertilized), under natural conditions, is a powerful means of influencing blossom bud formation. The problem is to make blossom thinning an economical practice. Trees producing a crop on all important branches each year yield very much more fruit than biennial bearing trees. Compare the check trees with the blossom thinned trees.

The latter produced nearly twice the fruit produced by the check trees, other things being equal. This block of Wealthy trees was given uniform cultivation and fertilizing.

We started tests of blossom thinning by various chemicals, using branches forced in beakers of water in a greenhouse. These tests were continued in the orchard at blossoming time last spring.

Trees	1920 estimated in boxes	1921 measured in boxes	1922 measured in boxes	1923 measured in boxes	1924 measured in boxes	Treatment
G 1	20	1/8	15 3/4	none	18	Check
G 2	20	1/4	22 3/4	2	19	Check
G 3	None	21 1/4	26 1/4	19	None	Blossom thinned in 1921
G 4	None	24	23	20	1/2	Blossom thinned in 1921
G 5	20	None	20	1/4	14 1/2	Check
G 6	None	13 1/2	10	12 1/2	None	Blossom thinned in 1921
G 7	None	17 3/4	25 1/2	22	None	Blossom thinned in 1921
G 8	None	16 1/2	21 1/4	22 1/2	None	Blossom thinned in 1921
G 9	None	20	15 1/2	16	None	Blossom thinned in 1921

There are a number of features of these tests that can be reported, although this is but a progress report. Iron sulfate was the most promising chemical tested. It does not noticeably interfere with pollination of uninjured blossoms. It is comparatively inexpensive, and does not form an undesirable compound with the residue of lime sulfur on the trees.

The pistils of apple blossoms were more easily injured by iron sulfate solutions than the leaves. This is comparatively the same principle as killing or preventing the growth of apple scab by a strength of lime sulfur which is not intended to injure the foliage. In the case of blossom thinning by iron sulfate solutions, we aim to kill all blossoms on a fair percentage of the spurs, uniformly over the entire tree. Good kills were secured with solutions as dilute as one-fourth ounce to one gallon of water. The tests indicated that it was quite important to wet the pistils with a fine spray. Coarse spray and low pressure gave less satisfactory results. Even a light breeze is sufficient to turn many of the blossoms pointing leeward. It was, therefore, desirable to spray against the breeze. We sometimes used twice as many gallons of solution as is ordinarily used in fungus control spraying.

One ounce of iron sulfate to one gallon of water gave good results in some cases, but caused considerable foliage burning as the weather became warmer. We tagged a random sample of spurs having all blossoms killed, but some foliage damage showed up later. On October 20, these spurs were gathered from the McIntosh trees, sectioned and

examined with a microscope. Thirty-two and one-half per cent were found to have formed blossom buds. This is a fairly high per cent, considering the foliage damage, which undoubtedly prevented many spurs from forming blossom buds.

The tendency is to under-thin apple blossoms and over-thin Japanese plums. Each blossom killed on a plum tree removes a potential fruit. The ordinary apple spur produces about six blossoms and may mature one fruit. We can thus kill five of those six blossoms without greatly affecting blossom bud formation or the crop on that spur.

Blossom thinning suggests a way of reducing the labor of fruit thinning on both pome and stone fruits. It seems reasonable to expect some benefit to the remaining crop from this early reduction in competition. The crop on the blossom thinned trees set fairly uniformly over the trees and did not seem to be reduced in quantity by the blossom thinning.

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Some Genetic Phases of Horticultural Development

By M. J. DORSEY, *West Virginia University, Morgantown, W. Va.*

THE development of our present varieties of fruit has been a long process and men in all parts of the world, representing great extremes in social advancement, have taken a part in what we now look upon as modern horticulture. They are still at work even with greater vigor and interest creating new things out of the old. It is important to recognize that one generation begins where the other left off, because it has taken a long time for us to realize that the time element has entered so extensively since the process of improvement began.

The studies of De Candolle were largely responsible for focusing attention upon the historical phase of the development. More recently the classical studies of Sturtevant have shown us how enterprising and persistant mankind has been in the search for edible plants. Sturtevant also gave considerable attention to the world exchange of edible plants. For us this phase of the subject is of even

greater interest because we live in the New World only recently discovered, speaking in horticultural terms, with large areas without a permanent horticulture and still in the trial and error stage.

It is not the intention, however, at this time to stress at length the historical phases of the subject, but rather to examine the processes by which improvement has taken place and then to stress methods of attack on some of the weak spots in our horticulture, derived and handed down to us from the past, but left to us to adopt and perfect.

Here, again, we have a phase of the subject which has been given considerable thought. The studies of Darwin on "Animals and Plants under Domestication," ably summarize the observations and thought up to that time. More recently from the horticultural standpoint, the writings of Bailey on the "Survival of the Unlike" and the "Evolution of our Native Fruits," are unusually illuminating. However, as recent as are these studies much has been accomplished since their completion, and the advances in the field of cytology and genetics have given us the first clue to the internal processes at work in the origin of varieties. Let us review, briefly, the steps in the development of varieties in the order in which they have been used.

The world over, men have seen differences in the several kinds of plants which they came to know through their personal contact with them. Some, of course, have seen greater differences than others, but even the instance of the conception of the species held by the early systematists only served to retard a wider recognition of what men knew of the universality of variation. The first step, then, in the development of varieties is the selection of the best individuals of a species as they occur in nature. The first efforts at improvement, therefore, follow considerable development in nature. When the first plantings were started about the more or less permanent abode of the American Indian, the best individuals of the species, as he knew them were chosen. This first step in improvement extends down to our time and with some fruits as the American plum, the blueberry and the fox grape has given promising varieties.

The next step comes with still further selection among those forms thus chosen for cultivation. The exchange of these types—by now given a name—with others doing likewise appears as a logical transition. That the processes described so far are effective can be seen by reviewing what has happened in America with the native fruits. With time comes the interbreeding among the best individuals under cultural conditions where still greater differences are brought out by protection from competition. It is under cultivation that an opportunity is offered for the first time in the history of the species for the survival of unusual forms, such as double, seedless, sterile, or unusually large variations. During this phase of development all forms of asexual propagation are forced into practice because of the innate human desire to pick out and use the unusual. Here tremendous progress is found in the development of varieties within the species, and forms are found which differ so much from the parent species that they are scarcely recognizable. It is clear to us now that in selecting the best types and isolating them certain fundamental

principles of genetics are being applied. In the first place, the species is being recognized as heterozygous, and in the second, individuals have been chosen and isolated which differ from others of their kind in genetic constitution.

There now comes with the next step the world exchange with the subsequent building up of interspecific varieties. This point of attack has given us variations which have extended the adaptibility of varieties over still wider territory. Herein lie new lines of promise and means of overcoming deficiencies which have not been used so extensively before.

Coming now to our time and dealing more specifically with our own efforts, we find ourselves using all of the above methods of attack. Other steps, however, have been taken. In addition to recognizing the fundamental nature of the slight differences between individuals within the species, as confusing as some of these now recognized as fluctuations have been, we have seen for the first time new light on the problem at hand. Mendel discovered plant characters. While great progress had actually been made in the improvement of both plants and animals, and our breeds and varieties were extant at the time of the rediscovery of his work, nevertheless modern genetic research has shown how it was done and has thus brought our operations still further under control. In order to see if we can better understand the success of our forefathers in drawing from the species such unusual things, let us briefly review some of the outstanding genetic conceptions. These can only be mentioned here in outline form.

At the time Mendel made his investigations, sex in plants was understood. Darwin was studying variations and natural selection. Weisman had set forth the idea of germinal continuity. Hybrids had been made, even before Mendel, and their likeness to the parents studied. Turning now to the field of cytology we find that the chromosome mechanism has been studied most intensively and correlated with character expression. Factors are located in linear arrangement in the chromosomes and irregularities in separation during division furnish an explanation of mutation. Studies are pushed of hybrid ratios, multiple factors in quantitative inheritance, pure lines, mutation, and more recently of doubling, trebling, etc., of the chromosome number in relation to character expression. As brief as this statement of genetic progress may seem it summarizes the findings of one of the most intensely worked fields in all biology and little room is left for doubt that the actual machinery of variation, heredity, and natural selection has been discovered.

Here, then, we have briefly followed our footsteps out of the unknown of the past to at least a workable understanding of the variety, the species and the hybrid. With our ax sharpened and our courage up, do we find the task finished? Let us look things over! Follow Sturtevant for a conception of the enormous range of man's attempt to develop food plants. See the sources of our varieties, note their native homes, the stage of development and their adaptability to our conditions. Note also in our own country the first attempts at

improvement in some of the native forms, such as grapes, plums, blueberries, and the native nuts, and it will be evident to the most optimistic that we have only begun plant improvement. At this point let us consider briefly our breeding methods in the light of the above progress in genetic knowledge.

As with other material the methods used in breeding horticultural crops must be adapted to the peculiarities encountered. With a large number of the vegetable crops simple roguing, isolation, or inbreeding and selecting, will yield valuable results in standardizing varieties. In the fruits the clone established by vegetative propagation avoids many difficulties and, all told, gets us by many rough places. With some of the crops, as the apple, loss of vigor in the seedlings has interrupted many attempts to build up homozygous parents, while self-sterility presents just as formidable a barrier in some other lines. As a result of the extreme heterozygosity of the tree fruits these two characteristics present serious difficulties in breeding technique, although it should be stated that in spite of the loss of vigor the building up of homozygous parents needs further study The selection of outstanding parents, working with large numbers, the use of back crosses, and interspecific crosses, present some of the most promising of the more immediate methods of attack. Here, as in any other line, the value of a cross from the economic standpoint is to be measured by what is obtained from it, and it is not infrequently the case that where a large number of varietal combinations are made the most promising seedlings come from only a few varietal crosses. This is valuable information and constitutes a distinct advance in the practical breeding of a crop. The striking success of some breeders, as Rogers with the grape, appears to be primarily in the fortunate selection of parents rather than in methods

Some confusion has prevailed in dealing with quantitative inheritance While many fruit characters exhibit a simpler type of Mendelian inheritance, others such as size, hardiness, quality, season, disease resistance, sterility, etc., have a more complex inheritance and many different degrees of expression are found in the progeny. This condition together with the relatively large chromosome number in some fruits, as with 20 for the reduced number in the grape, and 26 for the reduced number in the strawberry, still further complicates the breeding attack by increasing the number of possible combinations. When a limiting factor enters into the selections, such as hardiness or disease resistance, or there is an extensive suppression of gametes or seeds, as in some interspecific crosses, the chances of obtaining the desired combination is still further reduced, making it necessary to deal with still larger numbers, and to select parents even more carefully. These difficulties arising from inherent characteristics of the material explain why progress has been so slow, and why the time element has entered so extensively in the origination of outstanding varieties. Even then progress would have been slower had not the observations been so widespread.

Let us look now to the stability of the variety. Four distinct aspects of varietal permanence give us concern. (1) There is the

competition between varieties in the industry resulting in a rapid turnover with the short time crops, but a somewhat slower shift with the tree fruits. Note the so-called leaders of the nursery and seed trade. There is promise in this tendency because the question of merit and all round adaptibility must ultimately be the deciding factor, but especially with the tree fruits the economics of having varieties out of date is embarrassing. (2) In the seed trade the difficulty of getting seed enough to back up the extensive advertising of an outstanding new variety, or one suddenly gaining popular favor, and at the same time preventing substitution or mixing, has been encountered more than once. Unfortunately, the better the variety the greater the danger in this particular, especially if some such asset as high yield, disease resistance, earliness, or color is the consideration. (3) Some difficulties are now being experienced with the vegetatively propagated or clonal varieties which have heretofore been regarded as uniform and permanent. Aside from the broader question of age changes or senelity, the off-type or degenerate strains are giving most concern. The extensive work with the citrus fruits in eliminating unprofitable trees has created an interest in other fruits in this same direction. This point of attack with both top and root promises to be one of the fruitful lines of investigation in the immediate future. (4) Where seedlings closely approximate the varietal type, as in the sweet cherry and some of the native plums, the task of maintaining varieties true to type is almost impossible. On account of the pollination problem this mixing from seedlings is proving to be a difficult thing to handle in a commercial way with the sweet cherry.

Let us look now at some of our commercial varieties and see what improvements might be suggested. The list is long so we will consider only some of the most important. At the outset it will be clear that since every fruit has its use, this field is as fruitful for discussion as for suggestion.

Ben Davis and York Imperial are low in quality and not particularly attractive. Baldwin lacks hardiness in the north, and like York Imperial tends to bear biennially. Grimes and Golden Delicious are yellow apples of high quality, but the market preference is for red. McIntosh and Fameuse are high in quality but local in adaptation. Staymen Winesap, Delicious, and Arkansas, are inclind to be light bearers when young, and the Winesap group generally sets poorly. Northwestern has style, but is green, lacks quality, and like Baldwin is inclined to form a weak crotch. Northern spy comes into bearing late. Grimes is subject to collar blight. McIntosh, Jonathan, Delicious, Ben Davis, etc., are susceptible to scab, and York Imperial, Jonathan, Golden Delicious and others to cedar rust. So runs the story.

In the peach we have one big variety—the Elberta—low in quality and a Ben Davis to bear. It lacks hardiness in the fruit buds and the low quality of so much of the crop on the market limits repeat orders. Like Concord and Senator Dunlap, however, the strong points of Elberta are its wide range of adaptability and productive-

ness. These characteristics make it, all told, the most profitable variety. Crawford and J. H. Hale are light yielders, and still other varieties high in quality lack style. As grown in the north, we do not need an early or late Elberta as badly as a hardy Elberta. Much can be expected in the peach from breeding work.

Turn now to the pear and see how eagerly the industry awaits the appearance of that hardy, blight resistant Bartlett. The sweet cherry grower must ultimately turn to the breeding or test plot for standardized varieties of known fertility relationship with other varieties. Here, as in the plum, a genetic consideration must be reckoned with in the sterility problem. In the grape where flower type is an accurate index of the fertility relationship the work of Detjen, with Hope, is a striking illustration of the solution of a difficult commercial problem by the application of genetics. It would seem in the strawberry that an early berry as productive generally as Senator Dunlap, but with the style of Chesapeake would soon find a place in the market The persistence of Downing and Houghton is due partly to their productiveness and partly to our methods of using gooseberries. With a source of parents the equivalent of the English gooseberry the most advanced of our present varieties should be easily exceeded.

In the vegetables great progress is being made by the application of breeding technique With these shorter time crops many new advances have been made in bringing out special features such as early, seedless, or disease resistant varieties, but on account of the immense variety encountered in the different lines there is even greater need for building up types suitable for special needs, as for canning, or for large markets where immense quantities of a uniform product, of high grade, are demanded.

This phase of the discussion could be extended indefinitely, but these instances will suffice to illustrate some of the permanent liabilities growers assume upon making a choice of varieties. In many instances the shortcomings are serious and the surest way out in the end will be through replacement The most that can be said at the present time is that we are growing the best we have.

There are some tendencies at present in the varietal situation which are working more or less at cross purposes. In the market it is almost impossible to gain recognition for a large number of varieties, so the demand is for larger quantities of known grades of fewer varieties. This reflects back upon the nursery trade on the one hand, and on growers who have bearing orchards on the other, and calls for a narrowing down. If the number of varieties is cut down, some still produced in large quantities must go out. With market changes either for kind or quality, the tendency will be with the selected list to grow them over a still wider range of conditions, thus bringing adaptability as a limiting factor more to the foreground. This tendency will inevitably result in weeding out the varieties of more limited adaptability and the growing of the others over too wide a range, in this way again making it tempting for growers in some places to try something else.

We now come to the problem of covering the season. With Elberta to illustrate, this is done more or less successfully by distributing the early crop of the South first, and as this is consumed or decayed, as the case may be, moving on to the more northern centers for the supply. The very bulk of the Elberta crop is one of the most commanding features of the market and all of the great centers pray for a crop failure in the other, and if their prayer is not answered they juggle and jockey for the market. How would a hardy, productive J. H. Hale, adapted to New York and Michigan centers, affect the situation? Wouldn't this variety then take command of the market?

There is another danger with some crops where the bulk of the early production comes from a single center and that is picking too green. A market can be killed by this out of the season marketing of green fruit, low in quality, because repeat orders are checked and these after all determine the bulk of consumption.

If this situation is studied carefully on a broad scale it will be seen that it invites another tendency, namely, that of extending the list of varieties even if more local in adaptation, but covering the season more evenly. This tendency is also favored, by the influence of good roads and high freight rates, on the development of the local trade which may be even more discriminating in its preferences and demands. While the line need not be drawn too sharply between these tendencies, nevertheless, the entrance of state and national organizations into the marketing field tend to force the issue.

We can assume, on account of the number of people who have taken part in the origination of varieties, that what we have is, by common consent, considered outstanding if not the best. We can further assume that if it were not so difficult, costly, and time consuming, that even greater improvements would have been introduced. After all the frequency with which new varieties of superior merit come to the fore is relatively slow. Even those of us who have seedlings sent in by growers, or amateurs, realize how seldom our interest is aroused by their merits. From what I have seen of breeding plots at the various experiment stations, I think it may safely be said that in the fruits more things of merit come up in a decade for testing and discarding than come in from the entire state in an equal period. One of the things which makes it so difficult to get a variety before the public is the time element involved in growing an orchard, the expense of advertising, and the momentum older and perhaps inferior sorts have in the trade. This tendency, no doubt, together with the uncertainty of new creations, test them as we may, as grown over wide areas, by many different men and under varying conditions, is important because after all time tells us lots about a variety.

When the introduction of a new variety is contemplated it will be seen, therefore, that important economic as well as genetic considerations are to be dealt with. It will take time or money, or both, to place a new creation upon the market. If exceptionally superior merit is the offering, still certain things are to be determined for each locality in the way of adaptability, and excessive advertising will only hasten the judgment of growers whether the verdict be

favorable or unfavorable. The merits of new introductions must match the old standards, character for character, and then add a point, and even then the momentum or "good will" of the old must be reckoned with.

Finally, it will be evident that the complexity of the problem as shown by our research and by the trend in marketing will make further improvement in our horticultural crops even more difficult. On account of the nature of the processes taking place in reproduction breeders will repeat with only minor changes in control or protection much the same thing that has been happening in nature and under cultivation. Horticulturists, the world over, have been keen to pick out the results of these chance combinations and will continue to be. On the other hand, the present trend in the industry to nationalize varieties, while making it more difficult to shift or change, at the same time stresses more and more the shortcomings of varieties. Those characters affecting yield and continuous cropping, because of the bearing they have upon the stability of commercial enterprises, will receive most attention by breeders. With the further increase in the world exchange of species and varieties, new sources of variation and recombination are made possible and it is in this field that the breeding projects will prove most fruitful of practical results. Mutations or bud variations in our national varieties should be watched for even more closely in the future than in the past, because of their economic bearing. The problem of the species, will become of greater interest than ever, especially in those forms, such as our native nuts, where it may be said that improvement has just started. In all cases those varietal combinations which will give most in the way of superior character combinations in the progeny will be looked for more eagerly, because of the immense number of inferior seedlings resulting when even our best commercial varieties are used as parents. Every advantage will be taken then of heterosis, mutation, bud variation, inter-species crosses, inbreeding, selecting, roguing, and outstanding varietal combinations in future breeding projects. It appears reasonable, therefore, to expect that a consistent genetic study of our horticultural crops, on broad lines, will enable us to speed up, or at least partly control, the processes of improvement in edible plants, rather than to wait for things to happen.

Nursery Stock Investigations

By KARL SAX, *Maine Agricultural Experiment Station, Orono, Maine*

PREVIOUS investigations have shown that apple trees when set in the orchard maintain, to a considerable extent, their relative sizes in subsequent years. Since yield of friut is largely dependent on the size of the mature tree it is essential to select nursery trees which will make a large and vigorous growth in the orchard.

Differences in size of nursery trees can be attributed to bud mutation, variability of root stocks, variability in early development of the grafted bud, and environmental factors. Experiments have been conducted to determine the relative importance of these various factors.

BUD MUTATION

Buds were selected from productive and unproductive trees of the same age and variety and which were under apparently the same environmental conditions. Selections were made from two pairs of McIntosh trees, two pairs of Ben Davis, two pairs of Delicious, and one pair of Northern Spy trees. From 50 to 130 French crab seedlings were budded with buds selected from each parental tree. The one year whips from the productive parents were larger than the whips from the unproductive parents in five of the seven combinations, although in only two cases were the differences statistically significant. The two year old nursery trees from productive parents were superior in size in six of the seven combinations, but the difference is statistically significant in only one case, and in this case the selections from the productive parent resulted in only a seven per cent increase in size of nursery trees. In the other cases the buds from productive trees resulted in an average increased size of about two per cent. It is perhaps significant that in the two cases where the progenies of the productive trees were significantly larger the first year the differences in size decreased the second year from nine to seven per cent and from eight to four per cent, respectively.

ROOT STOCKS

Seedling apple trees used in propagating are extremely varible in size after several years' growth. Even in number one French crab seedlings there is considerable variation. The larger seedlings would be expected to give better results as root stocks than the small seedlings.

Correlations were obtained between size of the French crab seedlings and the size of the nursery trees grown on these seedling roots. The correlations between size of seedling and size of the one year whips was found to be .36, .38, .26 and .43, respectively, for the four

varieties, McIntosh, Ben Davis, Delicious and Northern Spy. The correlation between seedling size in the fall of 1922 and the size of the two year nursery trees in 1924, was found to be .42, .39, .38 and .45 for the above varieties. In all cases the size of seedling root seemed to have slightly more influence on the nursery trees as they became older.

Differences in Bud Development

The buds from a single tree vary greatly in their early development when budded on seedling stocks. The buds which begin growth early in the spring tend to result in larger whips at the end of the season than buds which develop late. The correlations between rate of bud development and size of the one year whips for the four varieties McIntosh, Ben Davis, Delicious and Northern Spy were found to be .23, .23, .30 and .59, respectively. The rate of early development of the bud has less influence on the size of the two year nursery trees as indicated by the correlations of .15, .10, .20 and .23 for the above varieties The decrease in correlation for the second year is statistically significant only in case of the Northern Spy trees. Although rate of bud development seems to be of little importance in controlling the ultimate size of the tree, it is perhaps worth some consideration because of its effect on the size of one year old trees.

The rate of bud development might be attributed to technique of budding, differences in comparability of seedling stocks or bud individuality. Experiments were planned to test these various possibilities. In the summer of 1923, five McIntosh buds were grafted into each of 77 seedling trees. If early bud development is caused by seedling compatibility we would expect all sized buds to grow equally well on a given seedling, but if the variability in bud development is due to the technique of budding, or to bud individuality, then we would expect as much difference in development of the five buds on a single tree as would be found in five buds on different trees. In the spring of 1924 we found that there was as much variation in development of each group of five buds as there was in five individual buds on different trees, indicating that differences in rate of bud development are not due to seedling compatibility.

The next question was to determine whether differences in bud development were due to the technique of budding, or to differences in bud individuality. Records were taken on parental McIntosh trees to get the variability in the development of five adjacent buds on the last year's growth, for comparison with the five buds which were grafted into the French crab seedlings. The rate of bud development was arbitrarily classed in five groups ranging from 0, or buds completely dormant to number five, or buds which had developed leaves more than one inch long. The analysis of the records on five adjacent buds on 75 branches of the parental tree gave a mean development of $2.17 \pm .03$ and a coefficient of variability of 37.3 ± 1.0. The 77 seedlings budded with five buds each, showed a mean bud development of $2.16 \pm .03$ and a coefficient of variability of 45.8 ± 1.3. In the parental tree only two branches had all five

adjacent buds in the same stage of development while in the seedlings 18 of the 77 trees had the five adjacent buds in the same stage of development. Evidently the technique of budding did not influence the rate of bud development in the spring and the buds on the French crab seedlings were as well developed as the buds on the parental tree. The buds on the seedling trees were, however, somewhat more variable in development as indicated by the values of the coefficients for variability. From these results it seems probable that bud individuality is the most important factor in causing differences in early bud development.

There is some evidence that differences in bud development may be controlled to some extent. Bud development of five adjacent buds on 75 branches was recorded in one year old McIntosh whips, on 10 year old McIntosh trees, and on a McIntosh tree about 30 years old. The average development on May 19, 1924, was $3.15 \pm .02$ for the whips, $2.57 \pm .03$ for the 10 year old trees, and $2.17 \pm .03$ for the mature tree. The coefficients of variability for the rate of bud development on the above trees was found to be $21.3 \pm .5$, $31.1 \pm .8$, and 37.3 ± 1.0, respectively. The number of branches with all five buds uniformly developed was 55, 19, and two respectively for the same trees. Similar results were found in comparing Ben Davis whips and mature trees. In general the younger and more vigorous trees develop their buds more rapidly and more uniformly than older trees If buds from young trees behave in the same way when grafted on seedling stocks, some of the variability in early bud development and size of one year whip could be controlled to some extent by selecting bud sticks from young thrifty trees. Experiments are now in progress to compare buds from young and old trees when propagated on seedling roots.

A novel method of budding was tried with some one year old whips. Buds from Delicious trees were budded upside down on the one year old whip where the permanent branches were desired. One bud was grafted right side up near the top of the whip to form the central leader. When these buds started development the following spring, they began to grow downward, but soon the young branch became horizontal and after it had grown about half a foot it began to turn up in the usual manner. All other branches which had a tendency to develop on the tree were pinched back to force the growth of the grafted buds. The resulting trees have branches which grow out almost horizontally from the trunk and which have a union that is practically unbreakable. This method may be of some value in certain types of experimental work and may have a practical application with certain varieties of apples.

Apple Stock Variation and Its Relation to Scion Growth*

By J. T. BREGGER, *Louisiana, Mo.*

INTRODUCTION

THE presence of inequalities between trees of the same variety under apparently the same conditions of environment has been a problem in economic horticultural practice since the early days of fruit-growing. Chief among the factors responsible for this variation is the matter of stock, and in the high variability of such stocks we find an important cause for much of the variation in the vegetative growth and productivity of fruit trees. Extensive studies have been made on the subject of stocks and their influence on the scion, but it was with the purpose of measuring quantitatively the effects of this stock variation in terms of scion-growth that this investigation was undertaken.

ROOT GRAFTING EXPERIMENT BASED ON TREE VARIATION

The object of this investigation was to determine if possible how much of the variation between trees in the same orchard, planted close enough together to eliminate undue soil differences, is due to the influence of the stock. For this purpose a number of pairs of apple trees were selected standing side by side and receiving similar treatment. Six year old trees of McIntosh were available for use on an experimental plot of the Cornell Agricultural Experiment Station farm. Alternate rows of these trees had been under consideration as a "Sod vs. Cultivation" experiment until 1921 at which time they were removed from the plot. The remaining trees in the buffer rows had received identical cultural treatments and showed no greater variability than the trees which had been removed. All of these trees, it may be mentioned, were the result of free-stock seedlings bench-grafted during the winter of 1915 16, grown in the nursery row for one season, and set out in the permanent plot during the spring of 1917. The planting distance being four feet each way, soil differences, especially between the trees of any one pair, were reduced to a minimum. The trees used in the investigation were chosen primarily with an idea to obtain pairs in which one tree was noticeably larger than the other, assuming that other factors being practically identical, if not equal, such differences must be due to stock variability.

The selected trees were dug at mild periods during the late winter and early spring, and all roots of grafting size cut off, bundled, and stored in a damp condition in a storage cellar until wanted for grafting. The scions used for the grafting work were McIntosh and Rhode

*A portion of this paper is an abstract of a thesis presented in partial fulfillment of the requirements for the degree of Master of Science in Agriculture at Cornell University.

Island Greening, using only scions from one tree for grafting on roots of any particular pair of trees. The grafting was done during the early spring by the whip or tongue method. The roots were first cut into pieces one-fourth to one-half an inch in diameter. This gave several pairs of piece-roots, matched perfectly between members of each pair. Scions were then matched likewise into pairs and the grafting accomplished, wrapping with unwaxed cotton string.

The completed grafts were wrapped consecutively in damp towel paper and stored in fresh evergreen (white pine) sawdust. After callusing, these were planted in rows in the greenhouse, the graft union well below the surface of the soil. Uniform soil of sufficient depth was available together with floor space, thus avoiding the troubles of using pots, or inadequate benches. A planting distance of six by eight inches was used, the grafts representing each pair of trees being six inches apart and side by side in every instance for the sake of direct comparison. Measurements were made of the length of a single bud growth, the summarized readings being recorded in Table I, together with the measurements of the trees from which the roots were taken.

Soon after starting the investigation, there became apparent several difficulties in connection with the work of propagation and growth of such grafts as were used in the experiment. The first one of these difficulties was experienced in the matter of callusing the grafts. Owing to the necessity of quick callusing, the cold temperatures of the storage cellar did not give the desired results. It was found, however, that when these grafts were brought into the laboratory and kept at temperatures (65° to75°F.), they developed good calluses on both roots and scions within a week's time. By putting the grafts in damp pine sawdust, all fungus activity was kept down and the callus formation proceeded without any handicap. It is the opinion of the writer that the pine sawdust when fresh is very antiseptic and makes the best possible storage material for grafts held in a condition of high temperatures and humidity. So successful was this method of callusing that without a single exception, some 400 grafts showed good callus formation and could be planted as early as 10 days after the time of grafting.

What proved to be the outstanding obstacle in successfully carrying this investigation to its completion, was the failure of the root pieces of the grafts to throw out new roots. Callus formation occurred in all cases and yet growth of the scion usually proceeded only to the extent of several inches, followed apparently by starvation as a result of the lack of the production of feeding roots to procure nutrients and sufficient water from the soil. In cases where root formation did occur, the scion showed a very vigorous growth, there being no question in regard to what was the cause.

On account of failure of the grafts to throw out new roots in the majority of instances, the writer was unable to carry the investigation very far. For this reason instead of giving the complete measurements of growth taking place from the time of planting through any specific period or periods, the measurements indicate the end

point reached by each pair of grafts at a time when one or both had reached their limit of growth. In many cases this end point in growth was followed by death, in others by inactivity without death, and in a very few by a short period of inactivity followed by a recommencement of growth, indicating an apparent postponed root development. The measurements which are summarized in Table I are nevertheless comparable between the grafts of any one pair of trees.

Relation Between Tree Variation and Growth of Grafts

In making an analysis of the complete graft growth data, it was found that the grafts made from roots of the larger tree of a pair showed the greater scion growth in the great majority of cases. Out of the total of 14 pairs of trees selected, the progeny of 11 pairs gave results apparently favoring the larger member of the pair; two gave results which slightly favored the weaker member; and one pair resulted practically in equality between the progeny of the two members. It was noted in addition that greater and more consistent differences were evident in favor of the root of the larger tree. It still remains to be shown, however, that such results are actually significant and indicate a more vigorous condition of the stock, which can be held as being directly responsible for the difference in size of the tree on one hand and of the scions grafted upon its unit portions of root on the other.

In order to justify a thorough examination of the data obtained, it became necessary to apply approved biometric methods of analysis. In connection with the present studies the writer made use of "Student's Method" as elaborated in Biometrika, Vol. VI (pp. 1-25).

Before making any detailed comparisons, it was first necessary to convert all measurements for each pair of grafts to a percentage basis. This was very essential owing to the fact that the pairs of grafts were not of the same size and, therefore, not intercomparable except on a percentage basis.

Making use of the mean percentage differences exhibited between grafts of each pair, computations were made which gave mathematically the odds against an occurrence of as large a difference being due to random sampling. To show in yet another manner the possible significance of the observed differences between grafts of A and B, these odds were converted into terms of the multiple of the probable error, making use of the table prepared by Pearl and Minor.* After computing the above mentioned statistical constants for the grafts from each of the 14 pairs of apple trees, the 14 average differences between pairs of grafts were taken as a basis and from this a similar computation was made to cover the entire mass of data accumulated. This as is shown by the table, indicates an even greater significance mainly because it takes into consideration larger numbers of variants.

*Pearl and Minor. A Table for estimating the Probable Significance af Statistical Constants. Paper No. 63 from the Biological Laboratory. Reprint from An. Rept. Maine Agr. Exp. Sta. 1914.

Upon examining the data, observed and computed, consistant differences were noted in favor of roots coming from the larger tree of nearly every pair. Assuming that differences equal to or more than three times the probable error are significant, we find that in approximately half of the trees considered, the scions grafted upon portions of their roots made an obviously greater growth when taken from the larger than when taken from the smaller tree of a pair. Among a majority of the remaining eight tree pairs, the data are strongly suggestive in favor of the more vigorous tree. Only in the case of two pairs is the evidence somewhat in favor of the smaller tree of the pair, but here the differences are small and not significant. The greatest difference is to be found when a summary of all trees and grafts under consideration is made, showing significant odds of 1666 to one, equivalent to about five times the probable error, against such differences being due to chance variation.

TABLE I.

Showing Comparison in Growth of Grafts made with Piece-Roots from Apple Trees of Unequal Size. (1922)

Tree No.	Height of Tree (feet)	Circumference (inches)	Number of Grafts	Total Growth (inches)	Average Growth (inches)	Differences	
						Odds	P. E.
1-A	9½	6¾	10	11¾	1.175	11	—
1-B	8½	4¾	10	9¾	.975	to 1	2.6
2-A	9¼	8¼	10	14¾	1.475	768	—
2-B	8¼	5¾	10	11½	1.15	to 1	4.8
3-A	10¾	7½	8	11½	1.44	332	—
3-B	10	5½	8	7½	.94	to 1	4.4
4-A	11½	7	8	10¾	1.35	4999	—
4-B	9½	5¼	8	6½	.81	to 1	5.4
5-A	12	6½	10	11	1.1	19	—
5-B	9½	5	10	8¾	.875	to 1	2.9
6-A	12	7¾	12	13½	1.10	5	—
6-B	12	6½	12	12½	1.06	to 1	2.0
7-A	9½	6¾	10	11	1.10	2	—
7-B	8	5¼	10	11¾	1.175	to 1	1.5(–)
8-A	11½	6¼	8	9¼	1.16	16	—
8-B	11½	5½	8	7½	.94	to 1	2.8
9-A	10½	6	11	13¼	1.20	1.1	—
9-B	9½	4¾	11	13¼	1.20	to 1	1.0
10-A	8½	7½	10	14¼	1.425	1427	—
10-B	7½	5	10	9¾	.975	to 1	5.0
11-A	12	7¼	14	17	1.21	1.9	—
11-B	9½	5½	14	17¾	1.26	to 1	1.4(–)
12-A	10½	6	8	9¾	1.22	2.4	—
12-B	8½	4¾	8	8½	1.06	to 1	1.6
13-A	12	8	15	19¼	1.28	49	—
13-B	8½	4¾	15	15¾	1.05	to 1	3.4
14-A	11	7½	20	32	1.6	65	—
14-B	10	5	20	25½	1.22	to 1	3.6
All A trees		—	154	198¾	1.39	1666	—
All B trees		—	154	166¼	1.08	to 1	5.0

TABLE II.

Showing Comparison in Growth of Whole-Root Grafts Made with Large and Small Seedlings. (1924)

Lot No.	Seedling Caliper (mm.)	Scion Caliper (mm.)	Number Grafts Made	Number Grafts Growing	Average Height of Whip (inches)	Difference P. E.
1	9	7	100	74	30.45±.512	.35±.652
2	6	7	100	91	30.80±.403	

When an attempt is made to account for the observed and calculated differences occurring between grafts of different origin, one is unable to make any definite statements. Without a doubt, consistent variations exist between equal piece roots of large and small trees and it is very reasonable to believe that when such variations are passed on to the scion, it is largely a matter of nutrition. Since in the observed grafts new roots had not formed in most instances to furnish nutrients from the soil, any difference in nutrition of the scion must have come directly from the root on which it was grafted. Any difference in scion growth might be then explained by an ability of the root to furnish more or less elaborated food to the scion, either by its possessing more stored food, or by its capacity to make it more quickly available to the scion. One would naturally expect the roots of a larger tree to contain more stored food than roots of a smaller tree on account of the larger leaf surface upon such a tree, but the question still remains as to whether a unit portion of the root of a vigorous tree contains more stored food than the same unit of a less vigorous tree under similar conditions of growth.

EFFECTS ON SCION GROWTH IN USING SMALL AND LARGE APPLE SEEDLINGS

In order to continue the work started in 1922, an investigation was started this past season along a slightly different line. Choosing from a bunch of ordinary apple seedlings, commonly used by the nurserymen, 100 seedlings of a small size and 100 of a large size were selected (measurements given in Table II). Scions used in this investigation were all Delicious from a common source. The resulting whole-root grafts, made with 100 small and large seedlings were all of the same length (10 inches), the only apparent difference being the diameter of the root. These grafts were then planted in four alternate rows in a field where the soil was as uniform as possible. The whole summer's growth is recorded, measurements being taken once during the season's growth and again after all growth had ceased in the fall of 1924. The only measurement taken was that of length, the trees being straight unbranched whips. The final measurements taken in November are recorded in Table II.

It will be noticed upon examination of the data in Table II, that there were no significant differences in the growth of the grafts made

from the small and large seedlings. Both groups showed the expected variation among individuals, but there was no appreciable or significant difference between individuals, or the mean growth of the two classes of grafts. The actual growth of grafts varied in the case of the small seedlings from 22 to 42 inches and in the case of the large ones from 20 to 46 inches. Taking the average, however, there is little or no difference between grafts made with large and small sized roots within the limits of the experiment. If anything, the advantage is shown by the smaller grafts and might be a result of better graft unions.

These results may, on first thought seem contradictory to what would be expected, and to the results secured in the foregoing investigation. There are, however, other factors to be considered. In the first place, previous investigational work, showing a variation among seedlings, nursery and orchard trees, does not show that the smaller seedlings actually make the smaller nursery and orchard trees. The size of seedlings is so largely dependent upon the competition they have in the row and upon the fertility of the soil that after these seedlings are taken up and planted at regular distances in the nursery row as grafts or as seedlings to be budded, they do not keep the same sized ratio. In other words, the factors which are so important at first, cease to operate for the most part and the growth factor becomes operative.

Another factor, in addition to that of crowding in the row and one which might account for the seedlings being large or small when dug in the fall after the first year's growth from seed, is the question of earliness or lateness of seed germination. This would play a very important part since seedlings usually grow until the end of the season. Seedlings which start to grow first, other things being equal, become the largest. All these factors taken together would more than outweigh the growth factor which seems to be the important one in comparing the growth of orchard trees. This factor, nevertheless, operates in the first year's growth of the seedling and accounts for the "runts" which are automatically eliminated in large numbers by the nurseryman before they ever reach the grafting table.

Conclusions

The facts brought out in the foregoing investigations indicate that some condition exists in the roots of an apple tree which through its effect upon the nutrition of the scion, or some other interrelation, has the power of modifying its growth. Thus size variations found among apple stocks could account for corresponding variations among trees growing on such stocks, provided these size differences are the result in the operation of the growth factor and not to other factors such as soil, crowding, duration of growth, etc. It still remains to be demonstrated, however, that the best growing trees of an orchard gain and hold their superiority because of the genetic constitution of the roots upon which they are growing. Our knowledge on the effects of stock variation upon scion growth is also incomplete, but based on all the evidence obtained, we cannot attach too much importance upon the use of stocks of the best and most vigorous type.

Uncongenialty a Limiting Factor in the Use of Disease Resistant Stock

By J. A. McClintock, *Experiment Station, Knoxville, Tenn.*

IN CONNECTION with studies on peach yellows as far back as 1891, Dr. E. F. Smith refers to peach buds growing on marianna plums, dying suddenly without signs of yellows.

While using the marianna plum in studies on peach rosette, the writer observed that peaches budded on marianna stocks sometimes died during the first growing season, after having made a vigorous and apparently healthy growth.

Because of its resistance to both the peach rosette and the root-knot nematode, the marianna plum would be a desirable stock upon which to propagate peaches and plums for the South, providing a good union could be obtained which would insure a strong, long lived tree.

One Florida nursery is using the marianna plum in propagating peaches to set in nematode infested soil.

The resistant qualities of the marianna plum have lead the writer to continue tests with it as a stock for peaches and plums.

In the spring of 1923, a test plat was set to one-year old Elberta peaches budded on seedling peach roots, and on marianna plum roots. The trees made a fair growth in most cases, but 42 per cent of those on marianna roots had died by the end of the first growing season; while 16 per cent of the trees on peach roots had died. This large mortality in the case of both peach and plum stocks might have been due to adverse weather conditions.

In the spring of 1924, all of the remaining trees started vigorous growth which continued throughout the summer. But on September 6 without any previous symptoms, two of the Elberta trees on marianna roots began to wilt as if moisture had suddenly been cut off. Within two days the leaves had turned yellow and the twigs were shrivelling. After photographing these trees they were dug, using care to take up as many of the roots as possible. In all cases the roots were discolored and dead or dying, the dead tissues extending up to the point of the union of the plum and peach. The peach tissues above the union appeared normal in color. The interior tissues at the point of union were exposed by sawing longitudinally. Examination showed that the union was good, only a small amount of dead tissue being present. It was also noted that there was very little overgrowth at the union. This would indicate that the peach-plum union was congenial.

In searching for the cause of the rapid death of the plum roots, platings were made from both large and small roots. Within 24 hours a rapidly growing fungus had spread out over a quarter of an inch onto the agar medium in which the root tissues were plated. Two other fungi grew out more slowly from the root platings. These fungi were transferred to tubes of agar and inoculations have been made on roots of healthy marianna and myrobolan plums to determine their pathogenicity. Healthy plum and peach trees have also been set in the holes from which the dead trees were removed, in an effort to determine whether pathogenic organisms are present in the soil.

Pending further findings, these observations are presented to learn if they are similar to those made by other workers; and to raise the question as to whether this lack of congeniality is due to a bad mechanical union, or to differences of acidity of sap which starves the plum roots, or to a pathological condition due to a definite organism.

The "Stockton" Morello Cherry

By W. L. Howard, *University of California, Berkeley, Calif.*

AT LAST we have a real dwarf stock for sweet cherries. This is the so-called "Stockton" Morello, a seedling of uncertain origin. It is true that Hooper speaks of the possibility of using Morello as a stock in his "Western Fruit Book," published in 1857, but how many of us knew about it? He says (page 268): "Dwarf cherry trees are produced by propagating the sweet or Duke varieties on the Mahaleb or Morello roots. They should be worked just at the crown of the roots."

Perhaps this is where we get the old, but erroneous, tradition that mahaleb is unsuited as a stock because it dwarfs the trees; for it certainly does not dwarf them to a degree worth mentioning. At least this is true under California conditions. Growers in that state have long wished for a stock that would make smaller trees than are produced by mazzard or even mahaleb.

The new dwarf stock is a seedling of the Morello type. It has been in common use by an Italian colony near Stockton, California, for at least 35 or 40 years. Since this particular type seems to be new to this country, I am proposing to call it the Stockton Morello. I have tried to trace its history and in this undertaking I have been materially assisted by Louis Vistica, an American born Italian of Stockton. Mr. Vistica is the only nurseryman I know of at the present time who is propagating it commercially.

According to our best information the Stockton Morello originated in or was brought to this country 60 or 70 years ago. If it was im-

ported it probably came from Dalmatia, or one of the other countries bordering on the Adriatic Sea. We first hear of it in California as being grown on Sherman Island near the confluence of the Sacramento and San Joaquin Rivers in Central California. An old inhabitant tells us that it was extensively grown there until 1873 in which year the island was submerged by a great flood and all orchards killed. We next hear of it near Stockton where there are at the present time many trees more than 30 years of age.

Trees of the Stockton Morello in general appearance closely resemble the English Morello. The fruit, when fully ripe, is very dark and has a colored juice, but is quite worthless for eating purposes. It is not only small, but very bitter. In these respects it resembles the western choke cherry (*Prunus demissa*) except that the fruit is not borne in racemes.

Some have thought it to be the Kentish Morello, but good authorities have pronounced it different. I sent a description of it to Mr. R. G. Hatton, Director of the East Malling Research Station in England, but he declared that it could not be the Kentish Morello. Some authorities list the Kentish as a synonym of Early Richmond. If this is correct, I am sure our Morello is something entirely different.

As to the possibility of its being an English Morello. Mr Stanley Johnson, Superintendent of the South Haven Experiment Station at South Haven, Michigan, says "After a careful study of the fruit and twigs, we have come to the conclusion that you have a different Morello than we have and as far as we know we have the typical English Morello. Our fruit is much larger, longer, and darker than the fruit sent by Mr. Vistica of Stockton. The wood growth, however, seems to be quite similar."

The Stockton Morello is used exclusively as a stock for varieties of sweet cherries by Italians of the Stockton district. In the first place it thrives in soils that are entirely too heavy for either mazzard or mahaleb. And in the second place it causes the trees to be distinctly dwarfish. It makes a satisfactory union with all varieties that have been tried except the Chapman. The latter can be used only by double-working, using one of the others as the intermediate.

The Stockton Morello is propagated exclusively from suckers which come up abundantly around the trees, which is the most objectionable feature connected with the use of the stock. However, they seem to do no harm if the land is kept cultivated. And cultivation is always necessary in California orchards, at least following each irrigation.

The stock exerts such a pronounced dwarfing influence that the trees of Napoleon (Royal Ann) and similar varieties, which naturally grow to a height of 25 and 30 feet and have to be harvested with 20-foot ladders, can be harvested with four-foot ladders or entirely from the ground.

They also have the quality of coming into bearing at an early age. The seedling trees are planted in the orchard 15 feet apart each way and the new growth is budded to the desired variety in late summer of the first season, let us say of 1925. The seedling tops are cut off in the spring of 1926, and in 1928 a small commercial crop can be har-

vested. The following year the trees should reach almost full size and produce commercial crops.

While the trees begin bearing early and fruit heavily and continuously, there is great danger that they may overbear and the fruit be undersized for either shipping or canning purposes. Overbearing, however, may be prevented by proper pruning.

From the very first the union between the Morello and the sweet cherry varieties seems insecure. As the trees become older they invariably overgrow the stock and look as though they would surely break off, but they never do. In the Italian settlement I have examined many orchards of different ages up to 30 years, but none of the trees showed breakage at the union.

At this point I should say that the Italians are very jealous of their trees and only very rarely will they sell sprouts to any one outside of their own race. And neither will they give a stranger any information. In this respect they run true to form, practicing as they do all of their old world customs.

To visit the Italian settlement with some one who is known to them, or who speaks their language is as good as a trip to rural Italy. As a rule their orchards are interplanted with grapes. The tree rows are perhaps 18 feet apart with two grape rows in between. Sometimes there will be a row of grapes along with the trees. The grapes are wine varieties and each vine is trained to a stake. No trellises are ever used.

All the cherry sprouts that arise are carefully dug up and either sold to neighbors or used to increase their own plantings. Sprouts that come up in line with the trees are always left and grafted in place. Hence the trees often stand very close together in the rows. It is not uncommon to see them two and three feet apart. Thus crowded, they are apt to be very slender and present a half-starved appearance.

Where soil conditions are especially favorable for tree growth (and is perhaps too wet for the grapes), and where the competition for light causes them to grow tall, the branches eventually fall over of their own weight and interlock thus furnishing a dense canopy through which the sunlight never penetrates during the summer. All side branches up to six feet are kept carefully trimmed off, according to the Italian habit. Of course nothing can grow underneath, not even weeds. More fruit would be produced if they thinned out the trees, but this is not the Italian way. Since these spots receive as much irrigation water as the rest of the orchard and the dense shade prevents the usual waste by evaporation, such places continue to be too wet for grapes. Incidentally this shows to what extent the Morello roots can exist and even thrive in a heavy soil.

In conclusion I feel that it is necessary to sound a word of warning about the planting of Morello stock in the near future. Owing to the heavy demand for the stock and the very limited supply, dealers are sure to begin propagating the trees from seeds and we have no assurance that they will be true to type like the suckers. Indeed such reports as I have indicate that these seedlings are far from satisfactory as stocks. It has come to my attention that one nursery

located outside of the state last year planted a large quantity of seeds and now has seedlings ready for delivery. Without definite proof to support my position, it is nevertheless my belief that there will be widespread disappointment if anything other than the suckers are used as stocks.

I am convinced that the success of the Stockton Morello is due to the purity and uniformity of the type and that this particular type happens to be one that forms a successful union with sweet cherry varieties and is able to adapt itself to wet soils.

In support of this position I may say that it is an old custom in European countries—especially on the Continent—to propagate trees from suckers wherever the parent stocks seem to be of a desirable type. While the large nurseries do not follow this practice—because it would be impracticable—some of the smaller ones do and it is generally practiced by individuals. And it is hard for us to understand to what extent small land holders who rarely plant more than a very few trees—one to half a dozen—in any one year, do their own propagating. It would seem highly probable then, that some immigrant took some of the Stockton Morello with him when emigrating to America or had roots sent to him after arriving. At least this is my own theory of its origin.

Influence of Stock on the Variety

By W. L. HOWARD, *University of California, Berkeley, Calif.*

DURING the last two years some striking cases of apparent influence of certain fruit stocks on the varieties growing upon them, have come to my attention. A few of these I have verified to my own satisfaction, while others are still being studied.

Case 1. A variety of European plum, when topworked on a Japanese plum and also on almond, was found to ripen its fruit from 10 days to two weeks earlier than normal. Both of these stocks have a short rest period and are apt to begin growing from three to four weeks earlier than the European plums.

Case 2. Another variety of European plum apparently was influenced in its ripening date by being topworked on early, medium and late varieties of peaches; the ripening dates varying according to the earliness or lateness of the peach on which it was growing.

Case 3. A variety of European plum topworked on seedling almond has always borne defective fruit, while the same variety in the same orchard growing upon peach, myrobolan, and on its own root, has uniformly borne perfect fruit. Since the same variety elsewhere on almond stock does not behave in like manner, I am inclined to believe this is a special case.

All of the trees studied and under observation are growing in Placer County, California, near the city of Auburn. Case No. 1

consists of President plums (*Prunus domestica*) topworked on Formosa (*Prunus salicina*) in 1920 when the latter were four years old. The Formosa trees are on almond roots. The orchard belongs to Mr. H. Herkomer of Auburn. A second orchard only a few miles away consists of President topworked on Formosa in 1919. The Formosa in turn had been grafted on Elberta peach in 1914. The peaches (growing on peach root) were planted in 1910. This orchard belongs to the Silva-Bergtholdt Company of Auburn, owners of extensive nurseries and orchards in Placer County.

Following the harvest season of 1923, I heard that certain orchards, or at least certain trees of the President, a famous shipping plum of the Auburn district, had ripened from 10 days to two weeks earlier than on other trees in the same orchard, and it was thought that the stocks they were on had caused this early maturity. Upon investigation, I found that all of the reported early ripening trees, always confined to definite rows, were originally Formosa, a Japanese variety that had been worked over to President. The Japanese trees were usually four and five years old when topworked to the President plum. The Formosa was unprofitable because it had proved to be a shy bearer, probably due to lack of cross-pollination, a subject which the growers had very little information on at the time. Since then we have shown how to make the Formosa bear good crops by planting varieties that would pollinate them.

It is a custom of most plum growers in the early shipping districts to grow several varieties, but all of them are on either peach or almond root. In some instances there are a very few grown on myrobolan root. Whenever a variety is not satisfactory because of bearing habits or prices received for the fruit, or from any other cause, they are apt to be topworked to something else. Thus it came about that when Formosa trees were grafted to President, there were whole rows in the same orchards of this variety growing on both peach and Formosa. When the last trees topworked, that is, President on Formosa, came into bearing, the owners were surprised to find the fruit ripening earlier than on the adjacent rows on peach stock. Also when this same thing happened the second year, when there was a much larger crop, they could no longer attribute the earlier maturity to the younger growth. The third season, 1924, I visited both the Herkomer and one of the Bergtholdt orchards and carefully checked up the situation as I found it. In both instances I found whole rows of President on Formosa ripening from 10 days to two weeks earlier than the same varieties on adjacent rows on peach. It was true that the trees of President on peach had been grafted some four years earlier than the President on Formosa, but as the latter, after four years from the graft, had settled down to what was considered their normal bearing habit, I cannot believe that the differences in age of the President tops had anything to do with the great differences in their dates of ripening.

In the Herkomer orchard, I found a few almond trees that had been topworked to President five or six years ago, and the fruit was ripening at least two weeks ahead of the same variety on peach. Mr.

Herkomer declared that they had been doing this right along every year since they came into bearing.

On a ranch belonging to J. A. Teagarden, located in the same general district, I found a single old Maynard plum, a Japanese variety, that was topworked to President four years ago. In 1923, the owner reported that the fruit was very much earlier than the same variety nearby on peach and this year, 1924, I found it to be ripening at least two weeks earlier and perhaps more.

It would seem then that an early growing stock immediately in contact with wood of a normally late growing and late ripening variety may exert a marked influence on the growth and maturity of the fruit of the latter. This is something new in horticultural practice and if this principle is found to hold good in all cases, it may be taken advantage of by growers in districts where early ripening is a desirable quality. Shippers of early fruit to eastern markets have found that while prices are always good for the first week or 10 days, there may be a sharp decline often amounting to 50 per cent immediately after that time. Therefore, if one grower, or a group of growers who may join together to ship in carload lots, can deliver their fruit to the eastern markets only a week ahead of their competitors, their profits will be very materially enhanced.

I have no evidence that the roots of a stock exert any particular influence on the ripening time of a variety. While many varieties of peaches and plums have been budded directly on almond seedlings in the nursery, or topworked on the trees in the orchard, no cases have come to my attention where the fruit seemed to be ripening any earlier than normally. I, therefore, can offer no explanation why the few old almond trees and the Maynard plum (a Japanese variety), when topworked to President, ripened their fruit so abnormally early. To my knowledge Japanese seedlings have not been used as stocks so I cannot say what effect they might have on varieties that could be grown upon them. As a matter of fact, there is a tradition that European varieties cannot be successfully grown upon *Prunus salicina* because the union is bad, but the success of the President on Formosa seems to disprove this belief. However, it should be remembered that a union may be bad where trees are budded in the nursery, when it would not be if established trees were grafted in the orchard. A good example of this is the Diamond plum (*domestica*) on the peach.

Case number two that was mentioned in the opening paragraphs of this paper consisted of a European variety of plum, Grand Duke, which had been topworked on three different varieties of peach, the Hales Early, Elberta and Salwey. The orchard, which was a very old one, was originally peach on seedling peach roots which were planted about 40 years ago. There were several rows each of the three varieties of peaches. In 1909, all were topworked to plums. It happened that the Grand Duke was the only one that was grafted on all three varieties of peaches. While I have not had an opportunity of personally checking up the ripening dates, I am assured by prominent growers of the neighborhood, among them Mr. J. A. Teagarden,

President of the County Farm Bureau, that there is approximately one week's difference in the ripening dates of the Grand Duke on the different varieties of peaches, that is, those on the Elberta ripen one week later than those on Hales Early, and those on Salwey one week later than those on Elberta, thus giving a range of two weeks in the ripening date of a single variety of plum which I can attribute to no other cause than the influence of the immediate stock it is growing upon.

This seems to supply additional proof that a late growing and late maturing variety like all domestica sorts are, may be influenced in its ripening date, not alone by the early growing habits of the stock immediately in contact with it, but by the habit or character of the stock wood of maturing its fruit early or late. This then introduces a new line of thought. In the case of the President plums on Japanese or almond stock, the early ripening of the fruit might be attributed solely to the early growing habits of the stock wood, while in the case of the Grand Duke on peach varieties, this quality of early growth in the wood does not seem to have been as important as its normal habit of ripening its fruit on some particular date either early, medium or late. However, I wish it to be remembered that I am reporting case number two largely from hearsay evidence, although I certainly have no reason for doubting the integrity of those who have observed the behavior of the trees. I have seen the trees, but I arrived too late to see any of the fruit while it was ripening.

Case number three is that of a variety of European plum, the Diamond, topworked on seedling almond trees. There were perhaps 40 or 50 trees in all and an equal number of the same variety of the same age consisting of nursery budded trees on either Myrobolan or peach stock. It was difficult to determine just what roots the latter were on, as in every case they had been planted rather deeply and being planted on a hillside, the soil had banked up around them so that without exception they had gotten on their own roots. This was easy to determine as great numbers of suckers were springing up around every tree and these in twig and leaf characters looked exactly like the Diamond.

The almond trees had been grafted from six to 12 inches above ground so that there was no trouble in identifying this stock. Also there were no sprouts arising from the roots as the almond never suckers. There were, however, enough water-sprouts found here and there above ground to enable us to positively identify the stock In every case where the Diamond was growing on almond, from 90 to 95 per cent of the fruit was defective. The trees bore heavily, but the fruit was worthless. It was so much trouble to pick out the few good fruits that it was not profitable to try to harvest them. For four or five years in succession the fruit has been defective. In most cases the fruits reached normal size, but in a few instances they seemed to be somewhat elongated, vaguely resembling fruit affected with plum pocket. However, pathologists have assured me that no parasite and certainly no fungus is present at all. On the surface of the fruits were slight depressions that looked like hail marks. When cut

open a mass of corky tissue was found which extended to the pit. In many the tissues near the pit seemed to break down, thus forming pockets of blackened or decayed flesh. Usually each fruit contained at least two or three blotches and often five or six. A single blotch was sufficient to ruin the fruit.

I have made rather wide inquiry to find other orchards where President is growing on almond stock. I have heard of some four or five such orchards, but there has been no complaint of defective fruit. On the other hand, I myself, have observed at least one other orchard in Placer County, only a few miles from the Teagarden ranch, where a considerable percentage of the Diamond plums on almond stock were defective. Also I should add that I found similar defective fruit in the same orchard where the variety was on other stocks, the exact kind not being determined.

I must conclude, therefore, that this apparent influence of the stock on a variety, in producing defective fruit, is probably due to local causes other than the stock itself. In conclusion, I should say that in the Teagarden orchard there was one tree that the owner was certain was grafted on almond root, but the union was below ground and soil washing down from the hillside had further submerged it to a depth of eight or 10 inches. The fruit on this tree was normal in every respect. However, there was a perfect thicket of sprouts around this tree which showed that although it may have started out on almond stock, it is now on its own roots. It is highly probable that the almond root has long since failed to function and this, incidentally, throws some light on the old question of whether it is really necessary to dig up a tree and remove the undesirable root after it has gotten on its own roots. It would seem that this extra work is not necessary.

I cannot close this paper without saying that the foothill region of Placer County offers the best field I have ever seen for the study of rootstocks. In the first place the region is an old one and during the past 40 or 50 years many stocks have been tried, and in the second place there is probably no section where so much top-grafting has been done. Styles in varieties of stone fruits have changed so frequently that some growers have been kept so busy jumping from one variety to another that they have never really been able to catch up with the times. This is hard on the growers' profits but they are certainly producing some very interesting material for the student of stocks and the interrelations of scion and stock.

Sod-Nitrate vs. Cultivation in the Apple Orchard

By J. K. SHAW, *Experiment Station, Amherst, Mass.*

ORCHARD soil management and fertilization have been a fruitful field for investigation during the past 10 years and many conclusions of value to the fruit grower have been reached. Still the results have been in many respects confusing and apparently contradictory which indicates that the subject is one for futher study. In some sections it appears that fertilizers are of little or no value in the cultivated orchard. In the case of orchards in sod, nitrogen has almost invariably given beneficial results and often to a most remarkable degree.

The purpose of this paper is to report the results secured from a comparison of the cultivation cover crop system without fertilizer, with sod plus 300 pounds of nitrate of soda per acre.

The experiment was begun in 1921 in an orchard of approximately three acres planted in 1911. It was planted on the filler system with Baldwin trees 40 feet apart, McIntosh in the center of the squares and the fillers one-half Wealthy and one-half Oldenburg.

The soil is classified by the Bureau of Soils as the Holyoke Stony Loam. The surface soil is underlain by a very compact subsoil beneath which is a layer of more open soil usually saturated, even in dry seasons, with seepage water from higher land. Probably the trees have not suffered materially from lack of water even in exceptionally dry years. The soil is of moderate natural fertility and had been somewhat neglected previous to the planting of the orchard in 1911. During the first 10 years the orchard was fertilized from time to time as seemed necessary, but only very moderate amounts of nitrogen were used. With the exception of two small portions of the orchard the soil management was the cultivation-cover crop system.

In the spring of 1921, the orchard was all plowed and harrowed and then divided into seven plots numbered from one to seven. The even numbered plots were treated with nitrate of soda at the rate of 300 pounds per acre. In the spring of 1922, these plots received nitrate at the rate of 150 pounds per acre on May 11 and were at once seeded to a mixture of Kentucky blue grass, red top and white clover. Little or no white clover has been evident in the sod, however. They have since been maintained in sod the grass being cut once each season and allowed to lie and they have received annual applications of nitrate of soda, 300 pounds per acre.

The orchard has received the usual care in the way of moderate annual pruning and a reasonably adequate spray program.

During the four years of the present treatment the trees have given moderate to good yields as shown in Table I.

TABLE I.

Average Yield per Tree, Pounds

Plot	1921	1922	1923	1924	Number of trees per plot
Baldwin					
1 Cultivation	2	9	117	53	4
3 "	4	35	74	2	4
5 "	45	134	61	6	4
7 "	2	80	67	315	3
Average	13	65	80	94	15
2 Sod-Nitrate	111	269	154	356	4
4 "	44	287	102	451	4
6 "	38	316	126	357	4
Average	62	291	127	388	12
McIntosh					
1 Cultivation	16	18	216	163	10
3 "	125	302	152	90	10
5 "	129	344	165	106	9
7 "	40	223	170	243	9
Average	78	272	176	151	38
2 Sod-Nitrate	135	342	273	361	10
4 "	118	343	209	366	10
6 "	125	434	263	471	9
Average	126	373	248	399	29
Oldenburg					
1 Cultivation	24	57	37	53	4
3 "	32	181	12	103	6
5 "	63	163	28	113	5
7 "	9	50	13	74	5
Average	32	113	23	86	20
2 Sod-Nitrate	54	173	1	153	6
4 "	30	164	29	128	5
6 "	16	246	1	261	6
Average	33	194	10	181	17
Wealthy					
1 Cultivation	3	134	0	123	7
3 "	100	155	88	64	7
5 "	99	107	123	56	7
7 "	34	110	47	128	8
Average	59	127	65	93	29
2 Sod-Nitrate	73	170	100	167	7
4 "	44	226	26	205	6
6 "	104	175	95	167	6
Average	74	190	73	180	19

This table shows an increasing divergence in yield. The sod-nitrate plots have generally shown a normal increase with age except with Oldenburg and Wealthy which in 1924 seem to show the effects of crowding as the tips of the branches are beginning to be interferred with by the overshadowing Baldwin and McIntosh trees.

One very significant fact may be noted in the yield of cultivated plots, one and seven which are larger than the yields of plots three and five. It has been stated that a portion of these plots was in sod in 1921. This sod was plowed under and it is the trees on these parts of the plots that are responsible for the greater yields. Determinations of moisture and nitrates were made in August 1924 on this old sod portion of plot one, on plot three which has been under cultivation from the first, and on sod-nitrate plot two. The moisture content varied from 14.44 to 15.71 per cent on August 13 and from 10 to 11.31 per cent on August 21. These differences can hardly be significant. No nitrates were found on either date on plots two and three. On the old sod portion of plot one there were on August 13, 9.26 p.p.m. and on August 21, 6.56 p.p.m.

While in 1924 the yields on plots one and seven averaged much higher than on three and five it will be seen that 1921 and 1922 they were smaller. As will be shown later these trees were much smaller then and this cut down the yields. The average yields of plots three and five in 1921 are practically the same as that of the three sod-nitrate plots when all four varieties are included.

TABLE II.

Average Size of Crowns

Plot	Baldwin	McIntosh	Oldenburg	Wealthy
1 Cultivation	71	69	73	56
3 "	71	84	87	69
5 "	71	84	79	59
7 "	76	74	64	54
Average	72	78	73	58
2 Sod-Nitrate	88	81	85	75
4 "	81	73	81	61
6 "	63	92	73	66
Average	77	82	78	67

While the yield of plants is of supreme importance to the practical man interested only in financial profit, it does not tell the whole story which the scientific investigator desires to know. Yield per tree will depend on several factors, the most important of which are (1) the size of the tree, (2) the amount of bloom (3) the percentage of set and (4) the size of the apples. Data on all these factors are available for this experiment.

In the autumn of 1923, an estimate of the size of crown was made on all the trees in this block. The largest tree of each variety was taken as 100 and the size of smaller trees estimated on this basis. While this is not a very satisfactory method it has some value and may be expected to show roughly the comparative average size of the trees growing under the two treatments. This is shown in Table II.

This table shows that the trees on the cultivated plots were somewhat smaller than those on the sod-nitrate plots due to the trees formerly in sod. Yet the differences in yield cannot be accounted for to any large degree to differences in size of crowns.

In any field plot experiment it is of great value to know the behavior of the plants before differentiated treatment is begun. Fortunately we have available here the trunk diameter of each tree each year beginning with 1915, excepting that of 1917. The method of taking this measure has varied somewhat in the early years, but since 1920 it has been by taking the trunk diameter at a fixed point indicated by a spot of white paint on the trunk.

The average trunk diameters of these trees are shown in Table III. and are also shown graphically in figure one.

TABLE III

Average Trunk Diameters, Millimeters

Baldwin

Plot	1915	1916	1918	1919	1920	1921	1922	1923	1924
1 Cultivation...	54	72	93	127	142	160	179	194	212
3 " ...	67	95	130	159	174	185	206	212	216
5 " ..	61	85	118	147	168	186	203	218	226
7 " ..	44	72	93	115	131	147	167	184	194
Average. .	57	81	109	137	154	170	189	202	212
2 Sod-Nitrate. .	64	93	124	157	180	207	229	244	256
4 " ..	69	89	122	157	176	198	217	239	253
6 " ..	69	93	143	170	189	213	227	249	263
Average. .	67	92	130	161	182	206	224	244	257

McIntosh

Plot	1915	1916	1918	1919	1920	1921	1922	1923	1924
1 Cultivation...	55	73	98	117	127	141	154	164	175
3 " ...	67	91	128	152	167	179	191	201	208
5 " ...	62	85	120	146	161	182	195	207	217
7 " ...	49	66	87	111	129	140	154	167	180
Average....	58	79	108	132	146	161	174	185	195
2 Sod-Nitrate. .	58	82	115	138	153	172	184	195	203
4 " ..	64	85	117	139	153	173	187	198	205
6 " ..	66	85	117	147	163	182	197	212	219
Average....	63	84	116	141	156	176	189	202	209

TABLE III.—*Continued*

					Oldenburg					
1	Cultivation...	36	45	57	68	73	80	88	96	111
3	" ..	48	65	86	107	116	123	131	136	139
5	" ...	44	61	83	110	118	128	135	142	153
7	" ...	34	46	63	76	88	98	108	114	118
	Average....	41	54	72	90	99	107	113	122	130
2	Sod-Nitrate..	41	56	76	94	104	119	127	136	142
4	" ..	39	58	77	94	105	118	126	133	137
6	" ..	48	66	89	110	118	131	140	148	153
	Average....	43	60	81	99	109	123	131	139	144
					Wealthy					
1	Cultivation. .	46	61	81	97	101	106	112	117	120
3	" ...	53	71	96	114	123	131	139	143	148
5	" ...	46	60	83	99	108	115	124	129	132
7	" ...	41	55	75	87	93	99	108	114	118
	Average...	47	62	84	99	106	113	121	126	130
2	Sod-Nitrate	45	63	91	110	117	129	138	146	150
4	" ...	48	63	85	99	104	121	126	136	142
6	" .	50	63	89	102	114	123	131	139	145
	Average...	48	63	88	104	113	124	132	140	145

A study of the table will show the increased growth on plots one and seven, probably due to the sod plowed under in 1921. The Baldwin's growth was about 34 per cent greater on these plots than on plots three and five; the McIntosh growth was 2 per cent greater, and the Oldenburg 17 per cent greater, while the Wealthy growth was about 4 per cent less. These differences between plots are explained in part at least by the different proportions of trees of these varieties on these two plots that were on the old sod areas. The proportion of trees on the old sod in plots one and seven were as follows:

Baldwin six out of seven; McIntosh eight out of 19; Oldenburg eight out of nine; Wealthy six out of 15.

Figure one shows clearly the difference in trunk diameter at the start of the present experiment and the increasing divergence since the differential treatment was applied. This is less striking in 1924, which may be due to the rather heavy crop. The Oldenburg and Wealthy may have suffered also from the overshadowing of the larger Baldwin and McIntosh trees. The Baldwins show the greatest growth probably due to greatest natural vigor and to lighter bearing for the size of the trees.

There has been made in each of the past three years an estimate of the per cent of bloom of each tree in this orchard. Trees that seemed to carry bloom on practically all strong spurs, on the tips of shoots and a good proportion of the lateral buds, were rated as having 100 per cent bloom. Few trees were so rated. Other trees were rated from 0 to 100 according to the amount of bloom they seemed to carry. While this may not be a strictly accurate way of measuring bloom it is rapid and it is felt that the differences in the averages

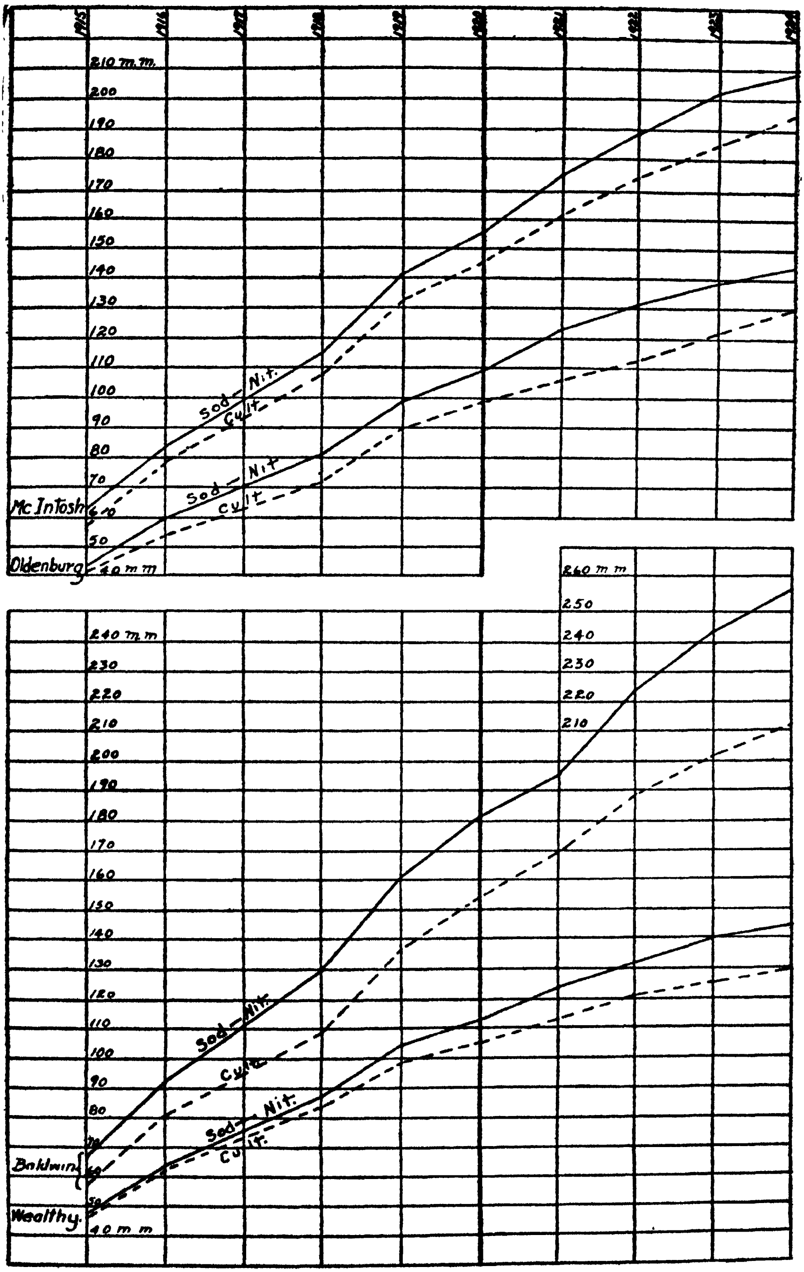

FIGURE I. Average Trunk Diameter.

shown in Table IV represent real differences in bloom with considerable accuracy. Every effort was made to avoid personal bias and to secure a fair comparison of the two treatments.

TABLE IV

Average Percent of Bloom

Plot	1922	1923	1924	
	Baldwin			
1 Cultivation	0	14	3	
3 "	2	12	1	
5 "	9	29	4	
7 "	32	5	38	
Average	11	15	11	12
2 Sod-Nitrate	19	9	26	
4 "	22	5	35	
6 "	21	10	30	
Average	21	8	30	20
	McIntosh			
1 Cultivation	51	55	48	
3 "	83	48	50	
5 "	77	47	66	
7 "	52	20	71	
Average	66	43	59	56
2 Sod-Nitrate	90	60	81	
4 "	87	48	71	
6 "	75	45	72	
Average	84	51	75	70
	Oldenburg			
1 Cultivation	41	34	63	
3 "	88	5	63	
5 "	59	34	51	
7 "	69	9	59	
Average	64	21	59	48
2 Sod-Nitrate	73	16	72	
4 "	67	17	66	
6 "	93	1	83	
Average	78	11	74	54
	Wealthy			
1 Cultivation	85	9	71	
3 "	67	56	29	
5 "	46	50	26	
7 "	83	12	54	
Average	70	32	45	49
2 Sod-Nitrate	78	29	62	
4 "	77	8	75	
6 "	48	33	50	
Average	68	23	62	51

Table IV shows the average bloom of the seven plots. This shows that on the whole the sod-nitrate trees have given more bloom though in the case of Wealthy and Oldenburg the averages, except possibly for 1924, are doubtfully significant. There is no very close relationship between bloom and yield, though it is closer on the sod-nitrate plots than on the cultivated plots.

It has been found by many investigators that frequently nitrate fertilization gives an increased set of fruit. In this experiment counts of the per cent of blooming spurs setting fruit have been made in the past three years on from two to eight trees on each treatment. This count has been made within 10 days after petal fall. Observations indicate that there has been more or less abscission of young fruits after the counts were made and this was greater on the cultivated plots. The set of fruit is greatly influenced by the amount of bloom on the trees, so in Table V the average bloom of the trees on which the set was taken is given.

TABLE V.

Average Percent of Spurs Setting Fruit

	Number Trees	1924 Spur Set	Per cent Bloom	Number Trees	1923 Spur Set	Per cent Bloom	Number Trees	1924 Spur Set	Per cent Bloom
Baldwin, Cultivation	—	—	—	5	82	34	3	77	43
" Sod-Nitrate	—	—	—	4	95	16	4	90	59
McIntosh, Cultivation	6	47	85	4	77	61	5	53	78
" Sod-Nitrate	6	48	88	4	92	53	5	84	82
Oldenburg, Cultivation	2	69	90	4	52	54	5	75	77
" Sod-Nitrate	2	82	93	2	58	88	5	84	82
Wealthy, Cultivation	8	74	93	8	58	91	4	94	61
" Sod-Nitrate	8	77	92	8	89	66	5	95	90

This table shows that in spite of the fact that the sod-nitrate trees often show a heavier bloom the set is better in every case though in some cases the difference is not enough to be significant. It is probable that here is the principal reason why the sod-nitrate trees have given better yields.

Very little data to show the size of the apples on the two series of plots is available. However, in 1924 a sample from the Oldenburg trees was run over a Cutler sizer and the comparative sizes of the apples came out as follows:

	Per cent Below 2½ Inches	Per cent 2½ to 2¾ Inches	Per cent 2¾ to 3 Inches	Per cent 3 Inches and Above
Cultivation	9.7	38.8	41.7	9.8
Sod-Nitrate	1.2	35.2	45.3	18.3

This shows that the apples from the sod-nitrate plots were the larger and observation indicated that this was true of the other three varieties in 1924 though it is doubtful if this was true in earlier years.

It appears that the larger yield on the sod-nitrate plots was brought about in varying degrees by larger trees, heavier bloom indicating more fruit bud formation, better set of fruit and larger apples. It is thought that better set has been the most potent factor especially in the past year or two.

Discussion

The results of this experiment indicate that on this soil apple trees cannot be maintained in a good growing and bearing condition by cultivation without fertilizers. What would have happened if the cultivated plots had received nitrogen is problematical. Probably an application of nitrogen in even smaller amounts than was used on the sod-nitrate plots would have increased yields so that they would have equalled, or possibly exceeded, the sod-nitrate plots. The behavior of the trees on the old sod portions of plots one and seven is similar to that of trees in other experiments at this Station. Probably the decaying sod furnishes the nitrogen and perhaps other nutrients needed by the trees for several years after which in the absence of added fertilizers both growth and fruitfulness decrease. It is believed that this is characteristic of many New England soils. The length of this period is variable and doubtless differs with different soils. There is evidence that it may vary from five to 10 or possibly even to 15 years.

The largest part of the cultivated plots had been under cultivation before this experiment was started and they suffered from nitrogen starvation sooner than the old sod that had been storing up nitrogen instead of using it in growth and fruit production, and perhaps losing it in other ways.

These trees showed a response to nitrogen in a deeper leaf color from the first while adjoining this orchard was another, also having nitrogen and no nitrogen plots which did not show this response, both orchards being in cultivation at that time. The soil in this orchard was probably less exhausted of soil nutrients, but the trees were merely smaller and this may have been a factor in causing the different behavior in nitrogen response. The smaller trees had fresh soil not yet occupied to exploit for needed nitrogen and other nutrients. In this experiment the soil was well filled with roots at the start and the trees suffered from lack of nutrients rather quickly.

In the light of present knowledge it cannot be contended that either the sod-nitrate or the cultivation cover crop system, is the proper way to grow apples, since there is abundant evidence to show that satisfactory results have been obtained by both systems. There are certain advantages in the sod-nitrate system. A sod orchard is cleaner and more satisfactory to work in at the spraying season. There is no difficulty from soil erosion.

Evidence indicates that maximum fruit bud formation is favored by a larger spur leaf area, and checked by too long continued growth of spurs and possibly shoots. In other words in order to get heavy bloom there must be produced quickly in the spring a large spur leaf area, but a short period of spur and shoot growth. Assuming a sufficient supply of available carbohydrates in the tissues, nitrogen seems to be the variable element most often controlling leaf production and growth. It seems then that a liberal supply of nitrogen early in the season, but quickly decreasing so as to check growth, might favor fruit bud formation. May not this condition be secured more often through a sod-nitrate program than by cultivation?

In a paper presented earlier at this meeting another fertilizer experiment that gave quite different results from this one is reported. In this case nitrogen apparently failed to be of benefit to the trees. This may be attributed to several causes. The soil type is different and the past history of soil treatment is not the same. Another difference that may be of greater significance is the age of the trees. In the other case the trees are recently planted while in this experiment the trees are now 14 years old. They have borne quite heavily and the tips of the branches are meeting so that the filler trees must be removed. It is probably this condition that makes possible the marked response to nitrogenous fertilizers. Evidently the nitrogen reserve on the plots that have been long cultivated with only limited replacement of nitrogen is so reduced that the trees are unable to grow and bear in a satisfactory degree.

The problem of soil management and fertilization of orchards is a complicated one and requires a great deal more study. It may be considered solved only when by examination we can tell the fruit grower what system to follow in order to obtain, not necessarily the maximum yield, but the most profitable returns from the orchard.

Performance Record of Apple Trees Over a Ten Year Period

By M. J. Dorsey and H. E. Knowlton,

West Virginia University, Morgantown, W. Va.

CONSIDERABLE interest is being taken in variability in fruit trees by recent investigators. This subject has been forced to the front because of the bearing of variability upon production, whether found in root stock or top. This report deals with the success of fertilizer applications in an orchard where conditions have brought out extreme variability in tree performance.

In recent years citrus growers in California have noticed that acre yields of fruit were declining. An extensive investigation by Shamel and his co-workers has revealed the fact that from 15 to 25 per cent of

the trees of many of the important varieties of grape fruit, lemon and orange are unprofitable being either unproductive, or else producing fruit of poor quality. In a few orchards 75 per cent were of these types. Hodgson in a recent paper has worked out a practical method of keeping individual tree records. Shamel, however, first advised the keeping of tree performance records in 1909. Needless to say the elimination of these unprofitable trees will materially lower production costs.

Apple trees have long been considered to be variable in productivity. Because of the "off year" habit of bearing the practical aspect of this condition had not been revealed. If a tree did not bear one year the grower assumed it would bear the next. Accustomed to consider the acre rather than the individual tree as his unit of production, the non-bearing of certain trees passed unnoticed. Fletcher, however, in 1913, reported that in an orchard of 1245 Ben Davis and York Imperial trees, 16 per cent were unprofitable, producing less than a barrel per tree over a four year period. Sax noted that in a Ben Davis orchard of 881 trees, 29 per cent were kept at a loss. Individual tree records had been kept since 1913. Both of these orchards were well cared for.

The West Virginia Experiment Station has been keeping individual tree records since 1914 in a block of 150, 20 year old Grimes, Ben Davis and York Imperial trees at Sleepy Creek in the Eastern Panhandle of the state. This block of trees has been given the fertilizer treatments shown in Table I, and the results up to 1920 have been reported in Bulletin 174 of this Station. Up to the present time this orchard has not shown any significant increases in yield from any treatment as measured by Student's Method, due in a large degree to the small numbers of trees used and to their extreme variability.

The individual tree records, however, in this orchard are very interesting. It will be seen from Table II that some trees have not produced a bushel of apples in the whole 10 year period. Many of the unproductive trees are not thrifty, but on the other hand a few are healthy and vigorous. No distinct tree types are apparent comparable to those noted by Sax, the upright habit of growth of the unproductive trees being due to the fact that they have never been pulled down by the weight of fruit.

The causes of variation in tree yields are assigned to three main causes by Sax, soil, root stocks, and scions. While it is difficult to differentiate between these it is probable that each contributes in every orchard. In the Sleepy Creek orchard soil heterogeneity appears to be the chief cause of variation in yield. With time, however, certain changes have taken place around some of the trees which have also been important. Because the soil is shallow and low in humus and initial fertility, an attempt has been made each year to deepen it by early spring plowing. While cover crops have been sown each year, generally in late July, considerable erosion has taken place in some parts of the orchard. In these parts each plowing has resulted

in considerable root cutting, as can be seen by projecting ends, or by digging a trench some distance from the tree. With many of the trees, however, root cutting has not apparently been detrimental.

The condition of each tree has been studied by noting the uniformity of bloom in the spring, leaf maturity in the fall, and cover crop growth. The variations noted in bloom have been striking; some trees bore practically no flowers, in others one or more limbs would have bloom on them while on still others the bloom would be evenly distributed.

In studying the cover crop it was noted that the rye showed an extremely spotted growth when viewed along the different plots. Under some of the trees the cover crop in early spring would extend up to the trunk on one side with little, if any, reduction in growth, but on the other on account of competition with the roots of the tree, the growth would be scant. Variations in this condition characterized the entire plot.

In the fall leaf maturity is very spotted on the different sections of the tree—corresponding in general to the root condition and soil depth. Where erosion and root cutting have limited root development on one side of a tree, bloom and fruit production are light and the leaf fall earlier. The nitrogen applications have tended to even up the trees as compared with the check plots. This tendency accounts in part, at least, for the increase in yield of the former, as shown in Tables I and II.

These considerations, however, do not appear to account for the performance of some of the trees. An examination was made of the root system of the third tree in the first check row which had produced only three pounds of fruit in ten years. Neither root cutting or soil erosion seemed to be the consideration in this instance. The roots appeared healthy and extensive. The total gain in trunk circumference in the 10 year period had been 12 inches, the same as an adjacent tree, which had produced 1731 pounds of fruit in the same period. Here, then, there appears to be a factor in yield which can be assigned primarily to the stock-scion relationship.

Turning now to the influence of the applications of nitrogen in an orchard where conditions are so variable, it will be seen that 46.4 per cent of the non-nitrated trees averaged less than one bushel per year while only 19 per cent of the nitrated trees fall in this group. Trees producing less than this amount the authors have considered unprofitable. Yet, this orchard has been well sprayed, pruned carefully, and cultivation with cover crops has been practised generally. Variability, however, has not been lessened appreciably, but the yields of all trees have been brought to a higher level. How, then, does the condition reported here differ from other studies in variation? That seedling apple roots are very variable has been noted by numerous investigators, Hatton (1920), Sax (1922), Dorsey (1919). That scions grafted on these variable seedlings will produce trees that are ununiform cannot be doubted. In the "stock and scion" orchard at the Maine Station the trees with Tolman roots are less variable than those with French crab roots. Other evidence of a similar nature

TABLE I

Individual Tree Yields (Pounds) Sleepy Creek Orchard 1914 1923

Row	Treatment	Tree Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Check	484	855	3	1731	—	35	340	941	29	163	1264	2112	253	73	1909
2	N P	423	1109	1057	—	—	471	631	1277	2347	913	1777	156	520	223	547
3	N K	332	553	862	954	—	1689	1409	1472	—	562	1950	1930	1776	2387	425
4	N P K	607	1133	758	594	—	1600	230	865	2887	2267	971	885	1910	1148	2206
5	P K	2099	539	1902	163	1940	742	389	509	1648	410	379	410	1098	187	15
6	Check	58	711	1828	263	—	80	592	1410	568	588	1577	419	153	91	1396
7	N	426	2141	1255	—	272	637	223	3216	1586	940	318	442	1425	567	—
8	P	1961	—	1138	471	24	597	—	1203	675	1184	904	643	11	39	97
9	K	544	19	93	1090	314	5	1336	53	746	1994	50	774	270	58	0
10	Check	3120	222	1783	99	82	400	—	1042	365	537	—	699	440	662	4
		Grimes					Ben Davis					York Imperial				

TABLE II

Productivity of Trees in Sleepy Creek Orchard, 1914–1923*

	Treatment Check	N P	N K	N P K	P K	Check	N	P	K	Check	N	-N	Total
Profitable............	7	10	11	13	8	8	9	9	6	7	43	45	88
Unprofitable.........	7	3	2	1	7	6	4	4	9	6	10	39	49
Per cent unprofitable..	50.0	23.1	15.4	7.1	46.6	42.8	30.7	30.7	60.0	46.1	19.0	46.4	35.7

*Trees averaging less than one bushel per year for the 10 year period.

could be cited. Granting its importance the unfavorable influence of the stock is, nevertheless, difficult to measure. One of the problems before the investigator of today is its elimination. The selection of favorable stocks that can be propagated asexually seems to be the most promising line of attack.

Shamel has found that variations in type and yield in citrus trees are due chiefly to inherent differences in the bud or scion. Webber, however, is finding that citrus stocks are variable and that they influence size of tree. A number of experiments with the apple could be cited in which investigators have attempted to perpetuate productivity by selection of buds from high and low yielding trees. Results have all been negative except in the experiment reported by Davis. In his discussion, Davis says, "the progeny of the poorest yielding tree has given on the average the lowest yields; that the progeny from the heaviest and most regular bearer has given the second highest; and that the progeny from the heaviest total yielder has given about 62 per cent more crop on the average than the progeny from the poorest yielding tree." The negative results gotten prove only that the selections made were fluctuations due to environment or stock. Many more must be made before the question can be considered answered. Bud variations, it will be recalled, have given us the Red Duchess, Red Spy, Collamar, Red Delicious, Red Gravenstein, and a host of new things in other fruits. Productivity, however, may be affected less by mutation than some of the other simpler characters.

It appears, therefore, that in this experiment we have a combination of many factors which cause variation in productiveness. From the applied standpoint, these are serious because as things now stand they seem to be accumulative. If such orchards are to be made profitable, changes will have to be made in management, which will counteract some of the present tendencies.

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Variations in the Japanese Pear Caused by Different Combinations of Fertilizer Elements

By A. KIKUCHI, *Tottori Agricultural College, Tottori, Japan.*

INTRODUCTION

THE origin of the cultivated pear in Japan is unknown. It may have had its beginning in the wild species of the country, or it may have been brought from China or Korea. There is no evidence to show when its improvement began, nor when the fruit reached the size, color and quality considered good for varieties of today. It is supposed, however, that as early as the eighth century of the Christian era, or even in a more remote period, the people cultivated the pear or had some knowledge of its cultivation.

A quotation from a book entitled, "Nihon-Shoki" believed to be a publication of the eighth century reads as follows:

"The Government advised the people to plant pear trees, chestnut trees, and other plants to increase the food supplies of the nation."

Although the history of the cultivated pear dates back many years, its commercial importance began about the latter part of the last century.

The Japanese pear is grown successfully in commercial quantities in almost every temperate fruit growing section of the world.

Statistics of the Department of Agriculture and Commerce of the Japanese Government for 1918, give the area of the Japanese pear orchards as 32,000 acres and the value of the crop as $4,600,000. The pear ranks next to the Satsuma orange and Japanese persimmon in the extent of its acreage and in its annual production.

Botanically, the present varieties of the Japanese pear belong to *Pyrus serotina*, Rehder,—formerly known as *Pyrus sinensis*, Lindley. More than 100 named varieties of this fruit are found in Japan, but less than 15 of the varieties are of commercial importance, most of which have originated as chance seedlings during the past 40 years.

Chojuro is the leading variety at present and includes probably more than 50 per cent of the commercial plantings. This variety surpasses others in its greater productiveness, finer quality and wider adaptability to soil and climate. Additional varieties such as Wase-

aka, Doitsu, Kozo, Nijisseiki, Imamuru-Aki, Taihei, Shinchiu, Taihaku and others have been grown commercially, but their production is limited to certain localities.

The Japanese pear orchard, or Japanese pear garden, as it is more fittingly called, is usually so small in area that the majority of orchards cover not more than two acres. The Japanese pear tree will grow on a great variety of soils, but it gives best results on deep, rich loam. The trees are usually planted at the rate of 300 to the acre or 12 feet apart each way.

Most of the commercial varieties are early bearers. They come into bearing the fourth year after planting and continue to yield for 20 years or more, depending largely upon differences in locality, or orchard management. The annual yield per acre of trees 15 to 20 years of age ranges from 18,000 to 28,000 pounds. Alternation of bearing or biennial crops occur rarely in the commercial varieties.

The root system of the Japanese pear is shallow; much more so than that of the European varieties. As a result of early bearing, heavy crops, shallow root system and thick planting, the pear tree, as grown in Japan, requires a greater amount of food materials than any of the other orchard trees. For many years organic nitrogenous fertilizers have been applied rather excessively, but little attention has been given to the effects of phosphorus and potassium.

Fertilizer experiments were started in 1909 at the Horticultural Branch Station of the Kanagawa Agricultural Experiment Station 27 miles west of Yokohama. There were six trees in each plot except the check which contained only three trees. The plots were designated and received applications of fertilizering elements as follows: N. P. K; N. P.; N. K.; P. K.; N.; P.; K.; and the check, no fertilizer. For three years prior to 1917 the annual yield of three trees in each plot was recorded. No other data were observed. It is probable that not enough plots and especially not a sufficient number of trees were included in each plot of this experiment to give a definite solution to the economic problems of fertilizing orchards. The author, however, modified the schedule of studies without changing these experimental plots. There is a significance and an interest attached to the response of the trees to nitrogen, phosphorus and potash, which were applied to these experimental plots, and these data are reported in this paper.

The Location of the Orchard and the Soil of the Experimental Plots

The soil was originally an alluvial deposit. It would be considered as having medium fertility, although the chemical analyses indicate that it is slightly low in phosphorus. The field was formerly used many years for vegetables and grains.

The surface soil is a dark brown loam, from eight to 10 inches deep. It overlays a compact clay subsoil which extends to a depth of from two to three feet. Mechanical and chemical analyses were made by Mr. K. Sakurai, the chemist of the Experiment Station. Samples of

soil were taken from 16 different portions of the field. Samples of the surface were taken from holes dug to a depth of three to six inches and the subsoil from holes carried to a depth of 12 to 18 inches. The mechanical analysis showed the surface soil to be about 63 parts sand and 36 parts clay; the subsoil, 40 and 59 parts, respectively.

The chemical analyses showed that the subsoil differs from the surface soil in having 50 per cent less humus, 70 per cent less phosphoric acid, slightly less potash, and about 40 per cent more nitrogen. The root systems of the trees are distributed mostly in that part of the soil which is five to 18 inches from the surface of the ground.

It is significant to compare the relative amounts of the more important soil constituents of the experimental plot with the average content of the soils of Japan.

Generally the soil in Japan is rich in humus, but the 6 per cent of humus in the surface soil of the experimental plots is slightly above the average amount in the soils of Japan.

The nitrogen content of 0.162 per cent of the surface soil is close to the average found in the soils of Japan. The amount present in the subsoil, over 0.2 per cent, is somewhat higher than the average content.

The average content of phosphoric acid of the soils of Japan is 0.120–0.150 per cent. The 0.107 per cent, of phosphoric acid in the surface soil of the station orchard is only slightly lower than the average.

The average content of potash in Japanese soils is about 0.2 per cent, therefore, the 0.357 per cent in the surface soil of the station is above the average.

The Plan and Treatment of the Plots

The Chojuro, the leading variety today, was used for this work. One year old grafted trees were planted in the fall of 1909.

The experimental plots contain eight rows and 45 trees. The trees were planted 12 feet apart in each plot and the distance between the rows of trees of adjacent plots was also 12 feet. For three years prior to 1913, farmyard manure, soya-bean cakes, wood ashes, sulphate of ammonia, superphosphate of lime and sulphate of potash were applied to help the normal growth of the trees in all plots except those in the check.

During these years, the quantity of actual elements in the fertilizers given to the trees and the rate per acre, are shown in Table I.

Since 1913, commercial fertilizers alone have been applied to the plots, and the trees in each plot have been given either a single element or a combination, corresponding to the experimental plan. Nitrogen in the form of sulphate of ammonia, phosphoric acid in phosphate of lime, and potash in sulphate of potash have been applied.

The annual rates of application per acre during the years 1913 to 1920, inclusive, are given in Table II.

Applications of fertilizers were made in the early spring every year and the fertilizers well spaded into the ground. No cover crops were

Table I

Rate Per Acre of Actual Fertilization Received by Plots Previous to 1913

Plot	1910 N pounds	1910 P_2O_5 Pounds	1910 K_2O Pounds	1911 N Pounds	1911 P_2O_5 Pounds	1911 K_2O Pounds	1912 N Pounds	1912 P_2O_5 Pounds	1912 K_2O Pounds
NPK	67	67	67	83	83	83	90	90	90
NP	67	67	17	83	83	17	90	90	17
NK	67	17	67	83	17	83	90	17	90
PK	17	67	67	17	83	83	17	90	90
N	67	17	17	83	17	17	90	17	17
P	17	67	17	17	83	17	17	90	17
K	17	17	67	17	17	83	17	17	90
nf	—	—	—	—	—	—	—	—	—

Table II

Rate in Pounds Per Acre of Actual Fertilization Received by Plots Subsequent to 1913

Plot Element	1913 N	1913 P_2O_5	1913 K_2O	1914 N	1914 P_2O_5	1914 K_2O	1915 N	1915 P_2O_5	1915 K_2O	'19 16. 17. 18. 19 N	'19 16. 17. 18. 19 P_2O_5	'19 16. 17. 18. 19 K_2O	1920 N	1920 P_2O_5	1920 K_2O
1 NPK	100	100	100	133	133	133	167	167	167	183	183	183	200	200	200
2 NP	100	100	—	133	133	—	167	167	—	183	183	—	200	200	—
3 NK	100	—	100	133	—	133	167	—	167	183	—	183	200	—	200
4 PK	—	100	100	—	133	133	—	167	167	—	183	183	—	200	200
5 N	100	—	—	133	—	—	167	—	—	183	—	—	200	—	—
6 P	—	100	—	—	133	—	—	167	—	—	183	—	—	200	—
7 K	—	—	100	—	—	133	—	—	167	—	—	183	—	—	200
8 check	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

grown under the pear trees on any of the plots. The trees were cultivated twice in the dormant period and three or four times in the active period every year.

The trees were trained uniformly on a horizontal trellis five feet five inches high, the so-called Japanese "Tana," which is the most widely used system of training in Japanese pear culture. The trees were planted so closely together that the roots of one tree often penetrated the soil of an adjacent plot. No attention was paid to this point during the several years previous to 1916. In the late fall of 1916, the boundaries around each plot were fixed by thick planks set into the ground to a depth of 28 inches. Root pruning was given all trees at the same time. The value of the observations made on the check plot was decreased by the fact that the author neglected to put boards around it until the fall of 1917. After the leaf-fall of 1917, each plot was trenched along the boundaries. Roots which had grown through the cracks in the planks were cut, and the boundaries were carefully repaired. Since then boundaries have been determined and retained annually.

In the spring of 1918, an effort was made to determine the direct effect of each element of the fertilizer on the fruit and tree growth. A single tree in each fertilizer plot was chosen for this purpose. These trees were treated with the same amount of the three elements and the same kinds of fertilizers as had been used in the NPK, or the complete fertilizer plot. Boundaries were fixed also by means of boards set in the ground at a distance of six feet from the trees. Tree two of NP plot, tree two of NK plot, tree four of PK plot, tree two of N plot, tree two of P plot and tree six of K plot, were used for this purpose.

Farmyard manure was applied to tree two of NPK plot as a nitrogen carrier. The amount of phosphorus and potash contained in farmyard manure was carefully calculated, and superphosphate of lime and sulphate of potash were fed to this tree in decreasing amounts. In other words, actual amounts of the three elements were applied equally to this tree with the others in the same plot, but all the nitrogen and a part of the other two elements previously supplied by mineral fertilizers were replaced by fertilizing material of organic origin.

During the spring of 1919, tree two in each plot was used for this plan and one crossed plot treated with three elements was made through all the fertilizer plots. Tree four of PK plot and tree six of K plot, were treated in the same way by applying one element or two according to the plan laid out at the beginning. Tree six of NPK plot was killed by the root rot disease (*Armillaria sp.*)* in 1915, and the data in this plot were secured from five trees.

*Seedlings or cuttings of seedlings of *Pyrus serotina* are commonly used as rootstocks for pears in Japan, and this root stock is occasionally attacked by the root rot.

The Effect of Nitrogen, Phophorus and Potash Upon the Size of Fruits and the Yield

As previously stated, no accurate record was kept in these experiments during the several years prior to 1917. In the harvesting period of 1917, however, the yield and number of the fruits were observed in four trees of each plot. During the three years from 1918 to 1920, the variation in the size of fruit has been accurately studied by the statistical method. Four trees were observed in each plot in 1918, and all trees in each plot in 1919 and 1920.

The data obtained from the check plot were irregular, hence should not be used with the same confidence as those secured in the fertilizer plot. This is probably the greatest defect in this experiment.

The number of pears harvested from each tree in the fertilized plots was usually from 200 to 300. When the trees were thinned, about 300 pears were left on each tree and at the same time the pears were carefully bagged each year. The plan was to determine the average size of fruits and yield of each tree so that it might be compared as exactly as possible with the same number of fruits raised on the other trees. But the uniformity of the number of fruits on each tree could not be maintained on account of the insect pests, diseases and other factors. During the blossoming period of 1919, certain trees were injured by pear psylla and this was especially true with trees two, three, and four of NPK plot, four of NP plot, one of N plot, and one of P plot, and a sufficient amount of fruits was not left on these trees.

The number of fruits, the average size of fruits and the size of yield of a tree have a close correlation with each other.

With the results for the four years it was found by comparing the trees of any one plot with the others, that if the number of fruits is not above 300 or below 200, and the difference between any two trees is much less than 50, then the number of fruits has no influence on the size of the fruit. The author was not able to determine the "critical point," above or below which the size of pear is influenced. It must be remembered also that the "critical point," if accurately studied, might not be the same in the plots which have received a different combination of fertilizers.

Unfortunately the yield of the check plot was so irregular that it can not be used in studying the greater yields of the plot treated with the fertilizers. The plots treated with only a single element are described, first, the plots receiving the combination of elements, second.

1. K. Plot. In the average size of fruits for the four seasons, the plot receiving potash alone surpassed the phosphorus alone by nearly 50 per cent, the nitrogen alone by 65 per cent and the combination of both by 88 per cent. In average yield, it also surpassed the other three plots by about 26 per cent, 42 per cent and 70 per cent, respectively. There is also a significant difference between the plots receiving potash and those not treated with potash. Potash has consistently benefited both the size of fruits and the yield in this experiment.

2. N Plot and P Plot. The plot receiving phosphorus alone took a higher position as compared with the plot treated with nitrogen alone in both the average size and the total yield. The former surpassed the latter in the size and yield three out of the four seasons. In one instance the results were reversed. Nitrogen alone or phosphorus alone usually had little influence on the size of fruit or the yield as compared with that of potash.

3. NP Plot. The plot receiving nitrogen with phosphorus has shown no gain over the nitrogen alone or the phosphorus alone. Apparently it reduces the size of fruit and yield as compared with the two plots treated with a single element. This is surprising with the comparatively lower percentage of nitrogen and phosphoric acid in this soil. There is only 0.174 per cent of nitrogen and 0.115 per cent of phosphoric acid in the surface soil, and 0.254 per cent of nitrogen and 0.039 per cent of phosphoric acid in the subsoil. On the contrary, there is 0.384 per cent of potash in the surface soil and 0.357 per cent in the subsoil. There is no apparent reason why a combination of nitrogen and phosphorus produced a retarding effect on the size of fruits and yield.

4. PK Plots. The plot treated with phosphorus and potash surpassed the potash alone only once in average size of fruit, but three out of four times in point of yield. The difference which appears is perhaps influenced by the number of fruits produced on the tree. Therefore, it is incorrect to conclude that phosphorus in addition to potash retards the size of the fruits or materially increases the yield. It should, however, indicate that phosphorus in combination with potash may show such an influence on the fruit.

5. NK Plot. The plot receiving nitrogen and potash shows the largest size and the highest yield, and is given a rank of one for the average of the four years. This indicates that nitrogen in combination with potash gives the more positive influence in increasing the size of fruits and yield of the pear when compared with phosphorus in combination with potash.

6. NPK Plot. The plot which has received the three principal elements has not given definitely a gain over the plot receiving nitrogen and potash. The difference between the two in 1919 is significant in the case of size, but it is probable that this depends largely on the small number of fruits in the complete fertilizer plots in this season. It has never surpassed the plot treated with nitrogen and potash in the yield during the four seasons. It may be noted again that phosphorus had little or no influence in increasing the size and yield of the Japanese pear in combination with other elements. The writer believes the observations stated concerning the different effects of each of the three elements upon the size and yield of the pear may have a practical as well as a scientific interest.

The Effect of Fertilization Upon the Quantity of First Class Fruit Produced

It is of interest to note the percentage of first grade fruit produced on the different plots. This was determined by grading the fruit

from each tree into three classes, namely number one, number two, and culls. The basis of separating the fruit into these classes was as follows: All fruits which weighed over 40.5 "Momme"† or 5.4 ounces, went into number one grade, and all fruits from 20.5 to 40.4 "Momme" were put into number two grade, and fruits smaller than 20.5 "Momme" were culls. The average results for three years are discussed as follows:

The per cent of number one fruit was small in the trees or plots not receiving potash as compared with those treated with potash. The per cent of number one fruit was increased to a remarkable degree in tree two of the plots not receiving potash in comparing with the other trees in the same plot. Number two fruit has been generally the largest in per cent, and number one fruit next to it in the plot treated with potash and phosphorus. On the contrary, number one fruit has been produced in the largest percentage in the plot which received nitrogen and potash. The per cent of number two fruit was next to that of number one fruit in this plot. It should be also observed that the coefficient of variability is always larger in the plots not receiving potash than in those treated with potash. The coefficient of variability has been almost directly proportional to the per cent of culls or inversely proportional to the per cent of number one fruit in each plot.

Variation in Number of Fruit Buds Produced on Trees of Different Plots

As stated, most of the varieties of Japanese pears are regular and productive bearers. This is especially true of the Chojuro variety. For this reason until recently little or no study has been made of fruit-bud formation of this variety. The author made a study of the variation in the number of fruit buds on each tree in each plot in the early spring of 1920.

In the experimental plots of the writer, each tree is trained in the space of 12 square feet on horizontal trellises. Four main limbs are regularly fixed to the trellises, and many fruiting branches are trained horizontally, so as to cover uniformly a given space for each tree. Most of the fruit buds are produced on spurs. Some of the lateral buds on current season shoots develop fruit buds after growth stops. The total number of fruit buds produced on both spur and current shoot per tree was carefully counted at the time of the winter pruning in early March of 1920. The average results are presented as follows:

The combination of nitrogen and phosphorus was most beneficial to fruit-bud formation. It seems apparent also that nitrogen is the most influential factor in the abundant formation of fruit-buds; that phosphorus is next to nitrogen; and that potash has no noticeable influence on fruit-bud development.

Prior to drawing conclusions from these results, a careful study should be made of the yield and the conditions of vegetative growth

†One "Momme" equals approximately 1/120 of a pound.

in each plot during the previous year. The Chojuro is able to develop blossoms in successive seasons on the same spur to a much greater degree than the other varieties grown in Japan. It is, however, reasonable to suppose that a greater yield exhausts the reserve food material much more than a smaller yield. If this is so, then spurs will produce fewer fruit-buds during years of large crops than during years when small crops are borne.

The author has analysed the data with two points in mind, i. e. the size of yield and the vegetative growth. The results show that the number of fruit buds in the check plot was exceedingly small in comparison with other plots. No new shoots were produced by the trees in this plot in either 1918 or 1919. All the fruit buds were produced on spurs. The amount of fruit wood and spurs was very small in the trees of the check plot. This is probably the principal reason for the small number of fruit buds in this plot.

Plots receiving potash have consistently shown a larger yield than plots not receiving this element. Notwithstanding this fact, the number of fruit buds produced is larger when no potash is applied than when it is used, with the exception of the complete fertilizer and check plots. The vegetative growth in 1919 was exceedingly vigorous in the complete plot and NK Plot. The order of rank of the plots based upon the vegetative growth produced in 1919 was NPK, NK, NP, N, P, K, and the n. f. plot. This relative order is shown more specifically later in this paper. The data in the judgment of the writer indicate that with the Chojuro the larger yields oppose the maximum fruit bud formation, while with this normally weak growing variety, a stimulation of greater vigor of vegetative growth promoted fruit-bud formation.

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The Missouri Cold Mix Oil Emulsions

By T. J. TALBERT, *University of Missouri, Columbia, Mo.*

IN 1922, the investigators of the Missouri Agricultural Experiment Station developed the fact that oil emulsions could be made without soap or heat. To do this, it was only necessary to use the materials which had previously been employed as stabilizers. These substances acted as emulsifiers without heat just as the soap had with heat.

The cold emulsions can be prepared more cheaply and easily than the oil soap emulsions. They also have another advantage in that they can be used with hard water, lime-sulfur, and in barrels or tanks contaminated with lime or lime water, without breaking down. They are compatible with all combination sprays. The valves of the spray pump used in making the cold mix emulsions are not damaged as is frequently true in making the boiled oil soap emulsions.

Field tests and investigations made by the Station have shown the cold emulsions to be just as effective in the control of San Jose scale as the boiled oil soap emulsion. Observations and experiments indicate that there is no more likelihood of injury in the use of one emulsion than the other.

BUYING AND MAKING OIL EMULSIONS

Commercial concerns dealing in spraying materials manufacture and sell lubricating oil emulsions. The grower may buy ready to use, therefore, either the cold mix oil emulsion or the boiled oil-soap emulsion. Where one is not prepared to make the oil emulsion properly he will usually obtain better results by buying the product already prepared and ready for dilution. Moreover, it is also generally true that the manufactured product is more uniform and less dangerous to the fruit trees in the hands of the inexperienced grower than the homemade emulsions.

DIRECTIONS FOR MAKING COLD EMULSIONS

Formula I		Formula II	
Engine oil	2 gal.	Engine oil	2 gal.
Water	1 gal.	Water	1 gal.
Calcium caseinate	4 oz.	Saponin	4 oz.

Formula III		Formula IV	
Engine oil	2 gal.	Engine oil	2 gal.
Water	1 gal.	Water	2 gal.
Copper sulphate (bluestone)	1/4 lb.	Copper sulphate	1/2 lb.
or		or	
Iron sulphate (copperas)	1/4 lb.	Iron sulphate	1/2 lb.
Burned lime	1/4 lb.	Burned lime	1/2 lb.

Making Cold Stock Emulsions

Formula I with calcium caseinate as the emulsifying agent was found to be one of the easiest to prepare and handle. The cost of 100 gallons of this spray was 38 cents as compared with 34 and 35 cents for Formulas III and IV. Formula I is considered superior, however, and worth the additional cost.

The oils used in making emulsions are of the cheap lubricating type, usually sold under the name of "engine oils," or of the type known as "floor oils" or "paraffin oils." Local oil dealers usually handle brands of oil suitable for sprays. Such oils should give a specific gravity test of 27° to 28° Baumé, and have a viscosity of 90 Saybolt or higher. The better the oil for lubricating purposes, the poorer it is for a spraying emulsion. The value of an oil for lubrication is generally represented by its selling price. It is probable, therefore, that the cheaper oils meeting the specifications mentioned above, will be the best for spraying. They should cost from 15 to 23 cents per gallon in 50-gallon lots.

To make 200 gallons according to Formula I, take eight ounces of Kayso, (calcium caseinate), make into a paste by slowly adding water and stirring until two gallons of water have been added. Then add this to four gallons of oil, mix, and pump as in making the Government oil soap emulsion. To make an emulsion according to Formula II substitute eight ounces of saponin powder, or the extract from one-half pound of soap bark, for the Kayso.

The stock emulsions made according to Formulas I, and II and III as described above, contain 66.66 per cent oil. To make a 2 per cent oil spray use three gallons of stock emulsion to 97 gallons of water. If Formula IV is used, the stock emulsion will contain 50 per cent oil, and four gallons will be required to 96 gallons of water in order to make a 2 per cent oil spray.

These stock emulsions are ready for use with any kind of water, or with lime-sulphur. They may also be put into tanks or barrels which have contained lime-sulphur, bordeaux or oil. A large enough quantity of the stock emulsion to last a day or two may be made by means of the power sprayer. The calcium caseinate emulsions will keep a long time. Oil sometimes separates out of the other emulsions after a few days, but can be re-emulsified by pumping again. All oil emulsions and proprietary or miscible oils stored in quantity should be thoroughly stirred before measuring out for use.

If it is desired to use 200 gallons of a 2 per cent oil spray emulsified according to Formula III, put four gallons of oil in a half-barrel or other container, then add one-half gallon of the copper sulphate solution from a stock solution containing one pound per gallon and one gallon of water. Stir up the lime and add one-half gallon of the milk of lime from a stock solution containing one pound per gallon. Mix the oil and water, etc., by pumping the mixture back on itself, using a coarse spray. After a minute's pumping, reduce the opening in the nozzle until a fine spray is obtained and pump the emulsion into another container. Then pump it back again. The emulsion

would probably be satisfactory with one pumping, but it is generally best to give it two. The finer the spray, the better is the emulsion obtained. Place the six gallons of emulsion in the spray tank and add 194 gallons of water making 200 gallons of spray.

To make the emulsion by means of a power sprayer, put the suction hose into a half-barrel containing the mixture, and pump it into the tank. Then pump it out of the tank into the container in which it is to be stored. It is essential if Bordeaux is used as the emulsifying agent, that the pumping be done immediately after mixing the materials. Haste is not necessary when calcium caseinate is used. Only freshly made Bordeaux or iron sulphate-and-lime mixture will act as a good emulsifying agent.

Cost of Engine Oil Emulsions

The relative cost of engine oil emulsions as compared to other materials used at the dormant or delayed dormant period, is given in the table below. The figures represent the approximate cost of materials for 100 gallons of spray at the strength recommended for orchard use. Of course in the case of the home-made emulsions the cost of preparation has to be considered, but we believe that in no case will this run over one-half the cost of materials, where the operations are extensive as in many commercial orchards. In general it may be said that the engine oil emulsions made according to the government formula that is, by boiling together oil, water and potash fish-oil soap, are made one-third to one-half as costly as lime-sulphur, and from one-eighth to one-fourth as costly as the proprietary miscible oils.

The oil emulsions have no fungicidal properties, so if it is desirable to use a fungicide with oil at the delayed dormant period the cost of the combination of oil and 4-4-50 Bordeaux approaches very close to that of lime-sulphur, if we consider the labor involved in making the emulsion and the cost of the Bordeaux mixture. By using glue or calcium caseinate as a stabilizer, oil emulsion may be used with summer strength lime-sulphur, but the cost of materials will not be decreased.

It is a well known fact that oil or fat may be mixed with water by means of a third substance called an emulsifying agent. The resulting mixture, which consists of minute globules of oil floating in the water, is called an emulsion. Each drop of oil is surrounded by a film of the third substance or emulsifying agent, which keeps the oil particles from uniting and forming larger masses of oil which would separate from the water. We may also have drops of water dispersed in a continuous mass of oil. This would be an emulsion of water in oil. We are primarily interested in emulsions of oil in water. Milk is such an emulsion and is similar to the emulsions used in spraying. It is well known in certain sections of the country that milk can be diluted with water. The same is true of stock emulsions of oil sprays.

The grower who desires to use oil must first obtain a stock emulsion, and then dilute it to the proper strength for spraying. The stock emulsions may be obtained from manufacturers in the form of

proprietary miscible oils, in which case the grower knows neither the nature of the oil nor the nature of the emulsifying agent. In the Middle West, stock emulsions of engine oils which have proven to to be efficient insecticides can be obtained at reasonable prices from manufacturers. These are made according to the government formula, from oil, water and potash fish-oil soap. There are no secrets connected with their manufacture. Sufficient stock oil emulsion of this type for 100 gallons of spray costs about one dollar. The Missouri Station advises growers who wish to use oil and who have not the experience and do not possess the equipment to make their own stock emulsion to purchase the ready prepared material from a reputable manufacturer, as they are apt to obtain a more uniform product and also one that is less likely to do injury to the trees.

Spray Material	Approximate Cost per 100 Gallons
Commercial lime-sulphur, 1–7	$2.10
Commercial lime-sulphur, 1–7, plus black leaf 40, 1 pt.–100 gal.	3.80
Scalecide (at 76c. per gallon), 1–15	5.06
Sunoco spraying oil (at 55c. per gallon) 1–15	3.66
Engine oil emulsion, Government formula, 2 per cent oil (Sold ready prepared by commercial firms)	.90
Home-made boiled oil-soap emulsions, Government formula, 2 per cent oil	.60
Home-made oil-Kayso emulsion, Missouri cold mix formula 2 per cent oil	.45
Home-made oil-Bordeaux emulsion, Missouri cold mix formula, 2 per cent oil	.42½
Home-made boiled oil-soap emuslion, 2 per cent oil, plus 4–4–50 Bordeaux	1.32

Proper Use of Lubricating Oil Emulsions

Oil emulsions have been used in Missouri for four years as dormant sprays for San Jose scale control. They are not recommended as foliage or fruit sprays. When directions for preparing, diluting and applying oil emulsions as a dormant spray are strictly followed, we believe that they are effective in controlling scale. Two per cent of oil is the strength recommended as a dormant spray. Free oil, which may rise out of an improper emulsion, or from the diluted spray mixture, is liable to cause injury to fruit trees. If free oil does rise, the emulsion is not safe to use. For best results a good emulsion must be maintained at all times. Lubricating oil emulsion is not fool-proof; but, if properly prepared and applied when weather conditions are favorable for dormant spraying, experience to date shows it to be safe. This also applies to the commercial lubricating oil emulsions and proprietary or miscible oils on the market.

Some have had injury and poor scale control from the use of improperly prepared and applied oil sprays, so we urge strongly, careful preparation of the oil emulsion sprays. Injury has been reported

from the use of oil sprays similar to lubricating oil emulsion, when applications were made immediately before periods of cold weather. Some also fear possible cumulative injury where dormant applications are repeated several years in succession. Experiments are now under way at the College of Agriculture which will determine whether such injury is likely.

Experimental Combination Sprays Inlcuding Oil

The Missouri Agricultural Experiment Station, Department of Horticulture, has been able to combine the dormant and first summer or pink spray for apple orchards. In so doing, time, labor, and the cost of equipment for making one spray, can be saved. The results obtained during the past two years have been satisfactory. From these results the indications are that the grower may wait to apply the dormant spray until the period for the pre-cluster bud, or cluster bud application. A 2 per cent cold lubricating oil emulsion may then be added to the lime-sulphur or Bordeaux arsenate of lead at summer dilution and the combination spray used for the control of all the insect pests and fungous diseases injurious to the foliage and fruit buds at that time. The main pests to be combated at that period are San Jose scale, aphids, curculio, canker worm, apple scab and black rot leaf spot.

A Bordeaux oil arsenate of lead spray, consisting of Bordeaux made according to the 3–4-50 formula, a 2 per cent cold lubricating oil emulsion, and one pound of dry arsenate of lead, was used in one set of experiments. In another, lime-sulphur, oil, arsenate of lead, consisting of lime-sulphur 1½ to 50, a 2 per cent cold lubricating oil emulsion and one pound of dry arsenate of lead, was employed. The investigations have been made during two seasons, 1923 and 1924. The sprays were applied at different periods, ranging from the time of the appearance of the first green leaves until after the cluster buds separated, but before the blossoms opened.

No material injury has so far been done to the young foliage or opening fruit buds. The tips and margins of the young apple leaves generally showed more browning or burning as a result of the application of lime-sulphur, oil, arsenate of lead than with the use of Bordeaux, oil, arsenate of lead. Careful observations have shown that no fruit buds were destroyed and the injured leaves were soon replaced by new ones.

Sucking insects like San Jose scale and aphids have been fairly effectively controlled at the pre-cluster bud and cluster bud periods. The spray has also controlled chewing insects like curculio and canker worms. Being a fungicide it has also been effective in the control of such fungous diseases as apple scab and black rot leaf spot. This spray seems promising in the control of aphids, especially when applied immediately following the hatching of the aphid eggs. This period usually occurs shortly after the appearance of the first green leaves.

Where the grower decides to combine the dormant and first summer spray, it is important that he start the spraying work in time to finish before the blossom or flower buds open, as the fruit and foliage

are often seriously injured by the application of oil sprays after the cluster bud period. It is also important for best results that the oil emulsion, which is used for the control of such sucking insects as San Jose scale and aphids, be applied not later than the period between the appearance of the first green leaves and the opening of the first flower buds.

The addition of the oil to summer strength lime-sulphur or Bordeaux may often be desirable because the grower may neglect or be unable to apply the dormant spray until after growth starts. Where this combination spray is used it is imperative that the spraying machinery and accessories be in first class condition and that sufficient materials be on hand to make the application. If delays occur the trees are apt to come into bloom before the spray can be applied to the entire orchard. The cluster bud or pink spray should generally be applied within a period of about seven days and the spraying work should cease while the trees are in bloom.

If San Jose scale and peach leaf curl must both be combated these troubles may be controlled by using a 2 per cent cold lubricating oil emulsion with Bordeaux made according to the 3–4–50 formula. In the control of peach leaf curl it is important that the work be done before the buds swell in the spring. For both San Jose scale and peach leaf curl thorough spraying cannot be emphasized too strongly. Unsprayed or partly sprayed buds may show the scale and curl.

Previous Use of Oil Sprays

Up to the present, oil sprays have never been generally popular with fruit growers. Stories of injury to fruit trees from the use of oils have circulated, and in many cases there is authentic information that such injury has occurred. Therefore, investigators have hesitated in many cases to recommend the use of the engine oil emulsions. We have as yet no definite information that injury has ever resulted from the proper application of 2 per cent engine oil emulsion to dormant apple and peach trees. Such injury as has occurred has been from improper applications, where the emulsion has broken and free oil has been sprayed onto the trees. Even under these conditions cases of visible injury have been rare. We have as yet, however, only three years' results. There is a possibility that there will be injury from applications of oil year after year, even though there may be none after one, two or three years.

In this connection it is of interest to note that proprietary sprays containing mineral oils with much the same characteristics as the engine oils, have been used for years in the Pacific Northwest without cumulative injury. The concentrations of oil were three or more times as great as we are using in the Middle West. This would indicate that no cumulative injury would result, yet until this has been proved experimentally under our conditions, we cannot say that the engine oil emulsions can be used continuously without any danger.

Some instances of injury have been reported as a result of using proprietary miscible oils when a severe cold period followed the

spraying. In 1923 and 1924 at the Missouri Station, engine oil sprays were applied at intervals beginning February 1. Several cold spells occurred between this time and spring, yet no case of injury to apples, peaches, or cherries was noted, even when oil was used in concentrations up to 10 per cent. Nevertheless, until this matter has been tested further we do not recommend the use of oils when there is danger that the temperature will drop to 20°F. or below immediately after the application.

It must be remembered, moreover, that any general adoption of oil emulsions means that a certain amount of injury will result from improper manufacture and application of the spraying materials. The successful making and use of this type of spray requires much more skill and knowledge on the part of the fruit grower than does lime-sulphur. The penalty for the misuse of lime-sulphur is merely failure to control scale. The penalty for the misuse of engine oil emulsion may be the loss of the trees. For this reason the new sprays should be adopted cautiously and with a clear understanding of the risks involved. They should be used only after the grower has acquainted himself with the methods of making and applying them under advice from the state experiment station.

Several investigators have reported that two per cent engine oil may be used safely on the foliage of fruit trees. From theoretical considerations and from experimental evidence it is believed that under Missouri conditions 2 per cent oil applications any time after the delayed dormant period may do injury. On stone fruits, severe foliage burning always resulted from such applications. On apples, burning resulted in many cases. Even where there was no visible injury, like burning of foliage or fruit, it is believed that the coating of oil may interfere with the natural functions of the leaves; that is, with the manufacture of carbohydrates. It is hoped that in time oils may be used at least up to the cluster-bud or pink stage for the control of scale and aphis. If we can use oil, Bordeaux and lead at the pink stage, it might be possible to omit both the dormant and delayed dormant sprays, with great saving in money and time. However, for the average grower with our present knowledge all applications of oil to apple foliage must be discouraged. Combinations of oil and dilute lime-sulphur may be made with the help of casein, glue or some other stabilizer, but have always caused severe burning when applied to foliage.

Summary

The lubricating oil emulsions are not recommended as fungicides. There is no evidence that they have any fungicidal value. When mixed with Bordeaux 3–4–50, however, the combination becomes a fungicide as well as an insecticide.

For the effective control of scale either liquid lime-sulphur, the lubricating oil emulsions, or miscible oils may be used. If there is any slight advantage in the matter of scale control, it is on the side of the oils.

From the point of view of scale control alone, the lubricating oil emulsion sprays are the cheaper.

From the point of view of possible injury to the fruit trees, lime-sulphur has a decided advantage as it has never caused injury when applied on dormant trees. However, the oil emulsions are being used extensively for dormant sprays, and if the emulsions are properly prepared and diluted, evidence to date points to the fact that they can be safely used on dormant trees.

Use ¼-¼-50 Bordeaux with every tank of engine oil-soap emulsion. Stock emulsions in which free oil has separated out and come to the surface, due to freezing, or any other cause, should not be used. Do not use a dilute spray mixture in which free oil has separated out and come to the surface of the tank. Stir all stock emulsions before measuring out for use. If you make your own emulsions, follow directions carefully, especially instructions to use a pump giving good pressure. The pressure given by a hand pump can usually be increased by decreasing the size of the opening of the nozzle.

Careful experiments and observations in Missouri have shown that San Jose scale can be effectively controlled with lime-sulphur, lubricating oil emulsions and miscible oils. A very thorough application is necessary and each spray must be used at the proper dilution. As many growers have failed to control scale with the oil sprays as with the lime-sulphur spray. It is not, therefore, so much a matter of which spray to use as it is of thorough spraying at the right dilution. One good dormant application each year should keep the scale well under control and prevent injury to the fruit and trees.

Two Years' Results on the Effect of Nitrate of Soda On the Yield of Strawberries

By S. W. Wentworth, *University of New Hampshire, Durham, N. H.*

THE experiments described in this paper were planned to throw additional light on the value of nitrate of soda as a fertilizing agent for the strawberry, and to determine the best time of the year for the application as well as the optimum amounts to be applied.

The proper cultural condition for the strawberry is still an unsettled question. Experimental evidence on this problem is meager and more or less contradictory. Publications on the culture of the strawberry vary widely in their recommendations as to kind and amount of chemical fertilizers to use and the most favorable time of the year for the application.

Chandler (1) working with a bed of strawberries in Missouri, which had previously fruited, obtained a decrease of 21.8 per cent in the yield when 310 pounds of nitrate of soda were applied per acre in the spring of the fruiting year. On another bed, where 120 pounds per acre were applied under similar conditions, there was a decrease in

the crop of 19.1 per cent. When the fertilizer was applied in the spring of the year in which the plants were set, in amounts varying from 105 to 360 pounds per acre, he obtained results as follows: an increase in yield of 33.2 per cent, a decrease of 53.5 per cent, and an increase of 2.1 per cent. The average of all trials where nitrate of soda was used alone gave a decrease in yield of 11.8 per cent.

In 1919, Brown (2) published a series of fertilizer experiments carried on at the Oregon Experiment Station. The first season's yields from beds fertilized with amounts of nitrate of soda varying from 220 to 440 pounds per 10,000 plants and applied during the spring of the fruiting year, gave an average increase in yield of 10 per cent due to the fertilizer. The following year these same beds treated in the same manner yielded an average increase of 34.8 per cent above the unfertilized plot. The third crop from these plots, treated as before, yielded an average increase of 10.5 per cent above the unfertilized plot.

White (3) obtained an increase in yield of 31 per cent from the early spring use of 200 pounds of nitrate of soda per acre on a bed in sandy soil in New Jersey which was fruiting for the first time.

Fletcher (4) states that "gains of 500 to 1000 quarts an acre from a spring top dressing of nitrate of soda are not infrequent."

Bailey (5) working with a variety of soils in Oswego County, New York, obtained small increases in yield when nitrogen carrying fertilizers were applied in the spring before the blossom period. Phosphoric acid and potash gave better results on the same soils.

The bed used for the 1922–23 experiment was set as an intercrop in a plum and cherry orchard which was planted during the spring of 1919. The soil is a medium loam and since the trees made a nearly uniform annual growth it would seem that it is of about the same fertility throughout the field. In the spring of 1920, an application of approximately eight tons of manure per acre was applied to the land between the tree rows after which an intercrop of corn was grown. In 1921 a similar application of manure together with a half ton per acre of 4-8-4 mixed fertilizer was applied, and a crop of potatoes grown between the tree rows. In the spring of 1922, the field was set with Senator Dunlap strawberries and divided into 16 plots, each containing 1260 square feet, or approximately one-thirtieth of an acre. The field was four plots long and four plots wide and rectangular in shape. Three different treatments were applied, each treatment being repeated four times. Four plots were left unfertilized for checks. Table I gives the treatment, yield and percentage increase or decrease of the fertilized plots, as compared with the average yield of the check plots. All berries were picked when they reached marketable maturity. The data are calculated from the number of quart boxes after being topped off ready for market.

The plan of having several plots with the same treatment has been used in these experiments. This reduces the errors due to variations in soil and moisture in different parts of the field, and also gives a check on the accuracy of the work by making it possible to calculate the probable error of the average. Bessel's formula for computation

of the probable error was used. The advisability of having in an experiment of this type a large number of plots of the same treatment, and a large number of check plots for comparison, is emphasized by the wide range in yield obtained both from similarly treated plots and from untreated plots. Even when four fertilized plots are compared with four unfertilized plots, the probable error indicates that the effect of the fertilizer was not measured with extreme accuracy. In four out of five trials by Chandler (1) the data represent a comparison of one fertilized plot with one unfertilized plot. In the fifth case one fertilized plot is compared with two unfertilized plots. Brown's (2) data are also taken from a comparison of one fertilized plot with one unfertilized plot.

The 1923–24 strawberry bed was set as an intercrop between two rows of an apple orchard which was planted during the spring of 1919. The soil at the south end of the orchard is a medium loam and gradually lightens to a sandy loam as the north end is approached. A gradual decrease in the annual growth of the apple trees toward the northern end of the orchard indicates that there is a gradual decline in fertility of the soil from the south to the north. A decrease in the yield of the check plots from south to north also indicates a lessening in fertility. In the spring of 1922, this field was fertilized with approximately 10 tons of manure per acre and a crop of sweet corn grown. In the spring of 1923, it was set with Premier (Howard 17) strawberries and divided into 16 plots, each one-twenty-eighth of an acre in size. The plots were numbered from one to 16, beginning at the south end of the orchard. Three fertilizer treatments were used, each treatment being repeated four times, while four unfertilized plots were maintained as checks. Four of the treated plots were fertilized with acid phosphate and are not considered in this paper. The treatments, yields and percentages of increase or decrease in yield due to the fertilizer will be found in the latter part of Table I. In view of the fact that the fertility of the soil decreased toward the north and that similar treatments were equally spaced along the tree rows, it was considered most accurate to use the Thorne (6) method of interpreting results, in which the theoretical unfertilized yield of any plot is calculated from the yield of the check plots nearest it.

Although the use of nitrate of soda on strawberry beds is a rather common practice in New Hampshire, the data presented here do not indicate that the practice is of any value. Taking the computed errors into consideration the first season's work does not indicate that the treatment affected the yield. In the second season yields appear to have been slightly decreased.

Measurements of leaves taken at random from the nitrogen fertilized plots and from the check plots, showed that those from nitrogen fertilized plots were on the average approximately one square inch, or about 20 per cent, larger than the leaves from the non-fertilized plots. The leaves from the nitrogen fertilized plots showed a greater tendency to wilt than those from the non-fertilized plots. This is probably due to a more rapid transpiration of moisture by the larger

TABLE I

Effect of Nitrate of Soda on Yield of Strawberries in New Hampshire

1922–23 Plots						1923–24 Plots					
200 pounds nitrate of soda per acre applied September 1, non-fruiting year.		200 pounds nitrate of soda per acre applied May 15, fruiting year.		200 pounds nitrate of soda per acre applied September 1, non-fruiting year, 200 pounds applied May 15, fruiting year.		300 pounds nitrate of soda applied per acre September 1, non-fruiting year.			100 pounds nitrate of soda per acre applied July 31, non-fruiting year, 100 pounds applied August 18 non-fruiting year, 100 pounds applied May 26, fruiting year.		
Acre yield in quarts	Per cent increase or decrease	Acre yield in quarts	Per cent increase or decrease	Acre yield in quarts	Per cent increase or decrease	Acre yield in quarts	Calculated yield	Per cent increase or decrease	Acre yield in quarts	Calculated yield	Per cent increase or decrease
5029.9	+23.6	4407.6	+8.3	3413.7	—16.1	3724.0	4662.0	—20.1	3532.0	4816.0	—26.4
4545.9	+11.7	4208.8	+ 3.5	4770.6	+17.3	3878.0	4263.0	— 9.0	3444.0	4585.0	—24.8
3059.4	—24.8	3284.1	—19.3	2886.5	—29.1	1708.0	2534.0	—32.5	4438.0	4140.5	+ 7.2
3802.7	— 6.5	3664.5	— 9.9	3854.5	— 5.3	924.0	1050.0	—12.0	1372.0	1792.0	—23.4
	1.0±10.5		—4.3±6.3		—8.3±9.8			—18.4±5.3			—16.8±8.0

leaves, whereby the supply of moisture in the soil is depleted more rapidly. This may account for the decrease in the crop where nitrate of soda was used. During the month of June, 1923, when moisture was very essential, the total rainfall was 2.26 inches. During June of 1924 the total rainfall was 1.22 inches. The crop was decreased on the nitrogen fertilized plots more severely in 1924. Possibly moisture is the limiting factor which determines whether nitrate of soda increases or decreases the crop.

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The Effect of Acid Phosphate and Muriate of Potash on the Vegetative Growth of Tomato Plants

By J. R. Hepler, *University of New Hampshire, Durham, N. H.*

THE experiment on the effects of acid phosphate and potash on the maturity of tomatoes, which was started in 1921 at the New Hampshire Experiment Station, shows definitely that more ripe tomatoes may be picked early in the season from the plots receiving acid phosphate than from those receiving other treatments. The data on vegetative growth presented in this paper were taken to attempt to explain this fact.

There were 32 plots in the experiment on which eight separate treatments were repeated four times and scattered through the field in such a way as to equalize any differences in soil and drainage. The plots were 20 by 34 feet including the space occupied by one row between plots which was used for a division row so as to prevent the overlapping of fertilizer treatments. Yield records were taken from 32 plants in each plot, set four by four and one-half feet and covering one-eightieth of an acre. All plots received an application of 20 tons of manure per acre. Plots 2–10–18–26, which received nothing else were considered as checks. Plots 1–9–17–25 received an additional 20 tons of manure per acre, making 40 tons total. In the remaining plots chemical fertilizers were used as shown in Table I.

The gypsum in plots 3–11–19–27 was used to determine whether it was sulphur or phosphorus in acid phosphate that affected the yield. The soil was acid and 6000 pounds of lime per acre were applied to correct the acidity.

The variety of tomatoes used is a strain of Bonny Best which has been bred in the University greenhouses for eight years. The same strain was used in all the experiments.

It was noticed that the use of acid phosphate stimulated vegetative growth early in the season and that the reason for the earlier maturity of the fruit was a greater bearing surface. The data in this experiment were taken by measuring the main stem of the plant and by counting the number of side shoots and measuring them. The figures given in the table are the total growth in inches for 32 plants, eight from each of the four plots receiving the same treatment The plants measured were chosen in such a way as to eliminate errors due to differences in soil and position. The number of blossom clusters was also counted.

The table shows very clearly the increased growth on the acid phosphate plots four, five and eight, amounting to 152, 113 and 155 per cent of the check respectively. The increase in the extra manure plot was only seven per cent, on the gypsum plots, 20 per cent, on the combination acid phosphate and muriate of potash plots 19 per cent, while the muriate of potash plots decreased 14 per cent of the check treatment.

On August 7, or three weeks later, the increases over the phosphorus plots were much smaller, being 76, 63 and 71 per cent, respectively, showing that the increased growth is an early growth.

In tomato plants that are neither over vegetative nor under vegetative, fruit clusters are formed near every second or third node and the number of clusters on a plant is closely correlated with its size. It takes the Bonny Best tomato about two weeks to produce blossoms at a node and six to eight weeks after blossoming to ripen the fruit.

The number of flower clusters recorded on July 31 may therefore be correlated with the growth recorded on July 17. Also the yield of ripened fruit September 17 may be correlated with flower clusters on July 31 and growth on July 17. A comparison of the per cent increase in growth for July 17 and the per cent increase in number of clusters for July 31, shows that they run very closely, the difference being within the probable error. The data on ripe fruit show big differences however, especially in plots three, four, five, six, and eight, where the increases are much higher. The increase was especially high on the acid phosphate plots. There was no difference in number of flowers per cluster and apparently no difference, in the various treatments, in the time it took an individual tomato to ripen after it had once set. Therefore, since the size of the ripened fruit averaged practically the same on all treatments, a higher per cent of the blossoms on the plots that received acid phosphate alone set fruit than where manure alone or muriate of potash was used.

TABLE I

Total Growth and Number of Clusters of 32 Plants Under Each Treatment and the Yield Per Acre

Plots Number	Treatment	Total Growth July 17		Total Growth August 7		Flower Clusters July 31		Ripe Fruit Sept. 17	
		Inches	Per cent of check	Inches	Per cent of check	Number	Per cent of check	Pounds per acre	Per cent of check
1 – 9 17–25	40 Tons Manure	1466	107	8456	107	391	114	4298	106.2
2 –10 18–26	20 Tons Manure	1371	100	7874	100	344	100	4048	100.
3 –11 19–27	20 Tons Manure 1000 Pounds Gypsum	1642	120	8495	108	421	122	6007	184.4
4 –12 20–28	20 Tons Manure 1000 Pounds Acid Phosphate	3461	252	13883	176	820	238	18069	446.3
5 –13 21–29	20 Tons Manure 500 Pounds Acid Phosphate	2915	213	12861	163	698	203	13330	329.3
6 –14 22–30	20 Tons Manure 1000 Pounds Acid Phosphate, 1000 Pounds Muriate of Potash	1637	119	9248	117	420	122	6473	166.5
7 –15 23–31	20 Tons Manure 1000 Pounds Muriate of Potash	1184	86	6249	79	325	95	2792	69.0
8 –16 24–32	20 Tons Manure 1520 Pounds Acid Phosphate	3494	255	13434	171	834	242	17508	432.7

The increases in yield in the acid phosphate plots four, five, and eight, which amount to 346.3 per cent, 229.3 per cent, and 332.7 per cent, are due, therefore, partly to the fact that these plots made their vegetative growth earlier than when acid phosphate was omitted, or where muriate of potash was used, and partly to the fact that the acid phosphate plots set and matured a higher per cent of fruit than the other plots.

Some Problems in the Analysis of Horticultural Material

By W. E. Loomis, *Cornell University, Ithaca, N. Y.*

CHEMICAL methods for the analysis of horticultural material must be direct and simple. They must require the minimum of special apparatus and elaborate manipulations. It is not necessary that these methods should determine with great accuracy the exact quantities of a given substance. It is essential that they fix the relative quantities of these substances present in different samples with dependable exactness. It is equally important that chemical separations shall fall along physiologically significant lines. The problem of the horticultural chemist is then not a problem of refinement, but of fundamentals. It is not often necessary to determine hexose sugars or amino nitrogen to the last fraction of a per cent, but it is always necessary to know that the hexoses or amino acids of one sample are not being compared with the pentoses or alkaloids of another.

The ideal procedure for a general analysis will separate a few fractions with a high degree of relative accuracy, and the various steps from preservation to the final determination of the different fractions will fit together so as to permit a rapid prosecution of the analysis. For general horticultural analysis, an initial separation in strong alcohol seems best to meet these requirements.

Alcohol as a Solvent

There are a number of chemists who advocate analysis of "living" material only. In most work this so limits the number of samples that can be taken under comparable conditions as to be impracticable. Even where it is possible, it does not eliminate the necessity of killing the material nor avoid the final mechanical separation of the inert substances. For most types of analysis it seems probable that an initial procedure which will rapidly halt enzyme action and will separate the plant constituents into the two physical classes, colloidal and noncolloidal, will be most valuable. Such a separation is relatively easy to make and is of presumably sharp physiological significance. Colloids form suspensions in water and so are sometimes classed as water soluble. Such suspensions, however, do not exhibit the characteristics of a true solution in their effect upon the boiling point,

freezing point, osmotic pressure and other constants. It is particularly significant that suspended colloids do not diffuse, so that while such materials could be suspended in water and apparently dissolved from finely ground plant material, they would be incapable of motion within organized plant tissue, and thus in the sense of mobility would be insoluble.

Alcohol has been used as a standard precipitant for colloidal suspensions. The strength of alcohol necessary and the completeness of the precipitation will vary with the material, but at concentrations of 70 to 80 per cent, plant colloids are largely precipitated. Not all amino acids are soluble in alcohol of this strength, but the insoluble forms have so far been reported only from grains. The other noncolloidal organic constituents widely distributed in plants are reasonably soluble in 80 per cent alcohol. Strong alcohol is thus adapted to the separation of the colloidal and noncolloidal forms of the various plant constituents.

The objection has been raised that alcohol is not a natural plant solvent. When a plant tissue is killed, or etherized, and ground, naturalness will no longer apply and separations must be made on the basis of chemical and physical properties.

Alcohol as a Killing and Preserving Agent

If alcohol is to be accepted as a suitable extraction medium, there can be little objection to its use as a preserving reagent. Hot alcohol penetrates plant tissue rapidly, driving out the air, coagulating the protein system of the cells and destroying the enzymes so that the sample is quickly rendered inert and in a suitable form for analysis. Hudson and Paine (J. Am. Chem. Soc. **32**.1350. 1910) have shown that invertase action is reduced, but not prohibited by cold 50 per cent alcohol. Other enzymes are more resistant than invertase and this coupled with the slower penetration of the cold liquid makes its use uncertain.

Link and Tottingham (J. Am. Chem. Soc. **45**:439. 1923) report important changes and serious losses in the carbohydrate fractions of samples dried at various temperatures, when compared with checks preserved in hot alcohol. Rosa and Auchter have informed the writer of similar experiences. Davis and Sawyer (J. Agr. Sci. **7**:255.1916) conclude that the commonly reported accumulation of maltose in plant tissue is due to faulty preserving methods by which dextrin is changed to maltose. This introduces a serious error in the total carbohydrate content since it is impossible to hydrolyze maltose in the first extraction because of the presence of fructose. Besides being easier and requiring less equipment than drying, alcohol preservation extracts a large proportion of the sugars and reduces the time required for complete extraction.

The Distribution of the Carbohydrates Between Alcoholic Extract and Residue

If the extraction of sugars is completed at the 70 to 80 per cent alcohol strength used in preservation, the reducing sugars, the free

pentose sugars and the disaccharides will be recovered in the alcoholic extract. On the authority of Davis and Sawyer, the difficultly hydrolyzed disaccharide, maltose, will not be present in quantity. Published analyses do not indicate large quantities of pentose sugars, but are of the order of two to five per cent of the total reducing sugars, so the alcoholic fraction will consist largely of hexose reducing sugars and the easily hydrolyzed disaccharides. The colloidal polysaccharides, starch, dextrin, pentosans, mannans, etc., will be largely, although in some cases not entirely, precipitated and recovered in the residue. The degree of precipitation decreases rapidly with alcohol concentrations of less than 70 per cent. Colloidal polysaccharides cannot be determined in the sugar extraction, but will be lost in clearing or give a gelatinous precipitate on the copper filter. The separation of colloidal and noncolloidal carbohydrates is, therefore, necessary to a satisfactory determination of sugars even when the colloidal fraction is not determined. A final sugar extraction with hot water will dissolve precipitated polysaccharides, and so defeat the purpose of the alcoholic extraction.

The Distribution of Nitrogenous Compounds Between the Alcoholic Extract and the Residue

The most complete work on the nitrogen compounds of green plants has been done by Osborne and his co-workers. (J. Biol. Chem. **53**:411. 1922; **61**:117. 1924.) Osborne ground fresh material and extracted it with water. He then precipitated out the colloidal substances by making the extract up to 53 per cent alcohol by weight. He is authority for the statement that all proteins were precipitated from the aqueous extract by this concentration of alcohol and that, when thoroughly washed with alcohol, the precipitate apparently contained no nitrogen other than that of protein like compounds. The same separation should be secured by extracting the tissue with the strong alcohol. If this assumption is true a convenient method of distinguishing between proteinaceous or combined, and nonprotein or mobile nitrogenous material, is available.

Such a method is required by the present trend of physiological experiments. It has been customary in the past to study carbohydrates and carbohydrate changes, or at most the relation of carbohydrates to total nitrogen. There is a growing tendency to recognize carbohydrate content as of significance only when deficient and to look to changes in the nitrogenous compounds for an explanation of the responses in growth and reproduction. While it is not conceivable that one group of substances can be isolated as responsible for plant behavior, the close relation of the nitrogenous compounds to the life activities of the cell makes them a promising subject of study.

In such a study a distinction between colloidal and noncolloidal nitrogen is easily made and serves to reduce the active nitrogen fraction so that it can be more carefully studied. The exact nature of the nitrogenous compounds soluble in strong alcohol is not known. They may be separated into inorganic, amid, amino and basic nitrogen, and

are presumably intermediate steps in the formation of proteins. Because amino acids are produced in the hydrolysis of proteins, they have been assumed to be the most important part of the noncolloidal nitrogen fraction. Osborne (*loc. cit.*) found that the basic nitrogen of the alfalfa plant also yielded amino nitrogen upon hydrolysis, and almost certainly amid nitrogen is an intermediate step between inorganic and higher organic forms, so that no sharp distinction is apparent. The noncolloidal fraction as a whole, may logically be assumed, however, to be more active and, therefore, more important in governing plant development than the colloidal fraction. Since these substances normally contain a minor portion of the total nitrogen of the plant, the necessity of determining them separately is apparent.

THE DETERMINATION OF NITROGEN IN PLANT EXTRACTS

The determination of total nitrogen in plant extracts is particularly difficult because of the necessity of reducing inorganic nitrogen in the presence of both basic and acid compounds of the substance. If reduction is carried out in acid medium as is common in the analysis of feeds and fertilizers, the nitrous acid formed from nitrates liberates some of the nitrogen of the amino acids. The salicylic-thiosulfate method does not recover nitrate nitrogen when any water is mixed with the sulfuric acid. Salicylic acid is volatile in steam, but there seems also to be an incomplete fixation of nitric oxide in dilute sulfuric acid so that free nitrogen is lost later in the digestion. The effect of moisture on the recovery of nitrate by the modified Arnold-Gunning method is given in Table I.

TABLE I.

The Effect of Dilution on the Recovery of Nitrates by the Salicylic Acid Method

Material	Total nitrogen by modified A.-G. method (mgs.)	Total nitrogen by P.-D. method mgs.)
0.7 gr. extracted celery residue con. 30.08 mg. protein nitrogen + 15 cc. $NaNO_3$ solution......	34.61	41.34
0.7 gr. c. p. sucrose and 25 cc. KNO_3 solution..	4.91	22.17
Same, but water removed before adding acid mixture......	22.28	22.20

The Arnold-Gunning method gave the same result on dry nitrate salt as did the Phillips-Devarda method. The Devarda method as modified by Professor T. G. Phillips, uses one-half gm of Devarda alloy in 100 cc. of N/10 NaOH, containing the nitrogen sample. Nitrates are reduced by distilling for 40 minutes into standard acid. Organic nitrogen is then liberated by digesting with 20 cc. sulfuric acid and distillation completed into the same flask by driving over 150–200 cc. of liquid in one hour. Five grams of sodium sulfate may be added to the digestion to break down acid hydrates and one-fourth

gram of zinc dust or granulated zinc, added just before connecting to the still, will reduce bumping. Paraffin or oil of some sort should be used in the first distillation. That this method is more accurate than the Arnold-Gunning on plant extracts is shown by the following analyses of a mixed plant extract containing 0.1 per cent sodium nitrate.

TABLE II.

A Comparison of the Arnold-Gunning and Phillips-Devarda Methods on Alcoholic Plant Extracts Plus Nitrate

Material	Total nitrogen by A.-G. method (mgs.)	Total nitrogen by P.-D. method (mgs.)
A mixed plant extract plus 0.1 per cent nitrate—all water removed.	17.57 16.76 16.45 15.96	20.50 20.34 20.72 21.11
Average . . .	16.69	20.67

The Arnold-Gunning method recovered nitrate nitrogen from the pure dry salts but gave low results with a mixture containing amino, basic and other soluble nitrogen compounds. It is not clear which form of nitrogen was lost. We have indications, however, that the loss is in the organic nitrogen since the total nitrogen fraction may be recovered from the extracts of some plants by the Gunning method.

Other experiments, the data from which cannot be given here, indicated that the alcohol must be completely removed from the samples used for the Phillips method. This was done by drying down an aliquot of the extract in the Kjeldahl flask.

The proportions of alloy and alkali cannot be varied appreciably.

It is not possible to separate nitrate nitrogen by making separate titrations on the two distillations as there is no intermediate end point in the distillation. Nitrate and nitrite nitrogen may be obtained from the difference of the Phillips and Kjeldahl determinations.

Significantly greater recovery of nitrogen is obtained by boiling for one hour than by distilling over the same quantity of liquid in a shorter time. In order to permit the longer heating, the quantity of all substances likely to cause bumping is reduced to the minimum. Note that only one-half gram of alloy and 20 cc. of acid are employed. For the same reason, the alkali used should be carbonate free.

DISCUSSION

For general analytical work on plant material, preservation in hot alcohol and an initial separation of colloidal and noncolloidal plant substances with the same liquid appears the most satisfactory. Colloidal and noncolloidal nitrogenous compounds may be separated by 60 per cent alcohol. Some colloidal forms of carbohydrate are appreciably soluble in alcohol concentrations of less than 70 per cent. Since sugars, amino acids, and other compounds usually determined, which are insoluble in 80 per cent alcohol, have not been reported in

vegetative tissue, it is suggested that a concentration of 75 to 80 per cent be used in preservation and initial extraction.

Commonly employed methods for determining total nitrogen including nitrates have been found unreliable on moist samples or on samples containing certain kinds of soluble organic nitrogen. The discrepancies observed may explain the difficulties which have been encountered in studying the movement and assimilation of nitrates in the plant. A modified Devarda procedure developed by Professor Phillips has been found the most reliable of the methods for total nitrogen in plant extracts that have been tested.

The importance of a more careful study of the nitrogenous compounds of the plant is emphasized. Because of the ease with which it can be made and because it distinguishes between those forms of nitrogen which can diffuse through semipermeable membranes and those incapable of such diffusion, the determination of the fraction of the total nitrogen content of the plant which is soluble in 60 to 80 per cent alcohol seems particularly valuable.

Summer Pruning the Central Leader

By W. A. RUTH and V. W. KELLEY, *University of Illinois, Urbana, Ill.*

AN EXPERIMENT to study methods of starting and developing framework branches was begun at Urbana in 1924. One method tried was summer pruning the central leader. This consisted in cutting off the tip as soon as the central leader had grown to the length where another framework branch was required, instead of letting it go until the dormant season, when it would have to be headed back severely. In our summer pruning, only an inch or so of the central leader was removed, instead of the third or more of its length which must be removed in dormant pruning. Five to six trees of three varieties, Winesap, Grimes, and Jonathan, were treated in this way. All of these trees were two years old when planted in the spring preceding pruning

Three interesting facts were noted. One was that very few buds back of the cut made in the summer were forced into growth. The last bud left always continued the vertical growth of the central leader. Five of the six Winesaps sent out one lateral branch below the cut, two of the six Grimes sent out one lateral, and three sent out two laterals. Three of the five Jonathans developed one lateral, and one developed two laterals. One tree of each variety sent out no laterals, the last bud only developing into a branch, which as just stated, continued the central leader, making an upright growth. A total of 17 trees developed 18 lateral branches.

In order to compare this with the effect of pruning the central leader in the usual manner when dormant, lateral branches back of the

cut were counted on a total of 13 trees of the same varieties pruned before active growth set in. Four Winesap trees averaged 4.8 developed laterals, three Grimes averaged 7.3 laterals, and six Jonathans averaged 4.8 laterals. By this comparatively severe pruning, at a different season of the year, and when internal conditions were undoubtedly much different, the results, measured in shoot development from lateral buds, were decidedly different.

A second point of interest, although not unexpected, was that, with only one exception, the second bud back of the cut always produced the strongest lateral branch. This seems to have a practical significance. By selecting the bud on the central leader which is located at the right height and *on the right side* of the central leader, and pruning just far enough above the bud immediately above it to preserve the latter, a lateral branch, later to become one of the permanent framework branches, can be placed correctly with the minimum pruning.

A third point is that this lateral branch, produced as the result of very light summer pruning, did not compete with the central leader, either in rapidity of growth or direction, which seems to be correlated. The angle with the central leader was always wide. The strong tendency for such unwanted competition as the result of severe dormant heading back is illustrated in the form of the head of most two year trees as received from the nursery. Usually the two highest branches have developed to about an equal length and at a close angle. In fact, even three branches growing with equal vigor and equally upright are not uncommon in such trees. Data gathered on Delicious and Golden Delicious one year whips dormant pruned, show that the first and second branches resulting, and frequently the first three, are almost invariably equal.

TABLE I.

Development of Branches on One Year Delicious Whips After Dormant Pruning in Late Winter

Tree Number	Buds forced into growth, counting from cut[1]										Buds developing most vigorous lateral[2]
	1	2	3	4	5	6	7	8	9	10	
1	D	x	—	x	—	x	—	—	—	—	2
2	x	x	x	x	x	x	x	x	x	—	1, 2
3	x	x	x	x	x	—	—	—	—	—	1, 2, 3
4	x	x	—	x	—	—	—	x	—	x	1, 2
5	x	x	—	—	x	x	x	x	—	—	1, 2
6	x	x	—	x	x	x	x	—	—	—	1, 2
7	x	x	x	x	x	x	—	—	—	—	1
8	x	D	x	—	—	—	x	—	—	x	1, 3
9	x	—	—	—	—	—	—	—	x	x	1, 9
10	x	x	—	x	—	x	x	—	x	x	1, 2, 3

[1]Dead buds indicated by "D." Buds which developed into branches indicated by "x".
[2]Indicated by number, from cut. When two or more branches developed with approximately equal vigor, as indicated by length, the number of the bud from which they all originated is given.

TABLE II.

Development of Branches on One Year Golden Delicious Whip After Dormant Pruning in Late Winter[1]

Tree Number	Buds forced into growth, counting from cut										Bud developing most vigorous lateral
	1	2	3	4	5	6	7	8	9	10	
1	x	x	x	x	x	x	x	x	x	x	1, 2, 3
2	x	x	x	x	x	x	—	x	x	x	1, 2, 3
3	x	x	x	x	x	x	x	—	—	—	1, 2, 4
4	x	x	x	x	x	x	x	x	x	—	1
5	x	x	x	x	x	x	x	x	—	—	1, 2, 3
6	D	x	x	x	—	x	x	—	—	—	2
7	x	x	x	x	x	x	x	x	x	—	1
8	x	x	x	x	x	x	x	—	—	—	1
9	x	x	x	x	x	x	x	x	—	—	1, 2
10	x	x	x	x	x	—	x	—	x	—	1, 2
11	D	x	—	—	x	x	x	x	x	x	2, 5
12	x	x	x	x	x	x	—	x	x	—	1, 2, 4

[1]The same foot notes describe this table as Table I.

Summer tipping back can frequently be practiced a second time during the summer, making it possible to locate a total of four framework branches in one summer on a two year tree; the first of these is one of the branches of the two year tree as received, the second arises from the second bud back of the cut on the branch chosen as the central leader, the third and fourth are similarly developed during the summer. The points of particular interest are, however, the easy location of these branches in the proper positions at a wide angle with the central leader, and pointing in the proper direction. This is done by attention to the second bud back of the cut, and tipping back during the active growing season.

The Distribution of Carbohydrate Foods in the Apricot Tree

By J. P. BENNETT, *University of California, Berkeley, Calif.*

INTRODUCTION AND METHODS

THE distribution of reserve carbohydrate foods has been determined in the apple tree by Butler and associates (1) and by Mitra (3). A similar study of the sugar-maple tree was made by Jones (2). This paper reports such a study upon the apricot tree for the first and second years in the orchard.

The trees used were Royal apricots budded upon apricot roots, pruned to whips and planted in February, 1921. During the first year a single tree was removed at intervals of about one month.

During the second year two trees were removed at one time, one of which had been heavily pruned during the dormant season by "heading," the other lightly pruned by "thinning" out branches. The intervals of removal during the second year were greater than during the first year, but were timed largely to show maximum differences which might appear in the trees.

In removing trees attempt was made to get nearly all the root systems. Lateral roots probably include in every case over 95 per cent of the total weight of the smaller roots. On removal the roots were washed free from soil and wiped free of excess water. Separation was then made into lateral roots, main root, trunk, first year and second year branches according to development. By first-year and second-year branches is meant respectively those new branches which developed during the first and the second year in the orchard. The separation of trunk and main root was made at the ground level, approximately at the point of union of bud and stock. Samples of each part, consisting of at least 50 per cent of the total fresh weight, were prepared for analysis by splitting and drying at 100°C. Wood and bark were included together in each sample. After drying the samples were ground coarsely, thoroughly mixed and a 10-15 gram sample ground to pass a screen of 40 meshes per inch.

Sugars were extracted from five gram ground samples with alcohol.* The reducing power of the extract was determined before and after inversion with citric acid, but only total sugars are reported on account of the small amounts present. Starch was determined as glucose in the residue from the sugar extraction after digestion with Taka-diastase and subsequent hydrolysis for two and one-half hours at boiling temperature with 1.10 dilution of concentrated Hcl. Hemicellulose was determined as glucose in the residue from the starch determination after a three hour hydrolysis with one per cent Hcl in a boiling water bath. All sugar determinations were made gravimetrically by the method of Munson and Walker.

The results of analyses are reported as percentage of fresh weight of tissues. This way of statement is believed to show more clearly than a dry weight basis the concentration of reserve foods in the tissues as it may be related to the nutrition of the tree The water content of different parts of a tree vary so much from season to season that it obscures comparisons made upon a basis of dry weight. And the activity of a plant can hardly be considered apart from its water content.

Strictly speaking free reducing sugars should perhaps not be considered as a part of the reserve carbohydrates. But the amount is so small that its deduction would hardly affect the totals. Free reducing sugar forms a part of the total available carbohydrate foods and bears the same ultimate relation to the living tissues as starch or sucrose. A part of the reducing sugar present after inversion

*Much credit is due to Messrs. D. C. Caudron and H. E. Thomas for painstaking effort with the analytical work.

may not have come from sucrose but from glucosides. The amount, however, would have been so small that no attempt was made to separate it.

Discussion of Data

The sugars were found somewhat lower in concentration than was found for the apple in the work cited above, taking into account that the data there were reported on a dry weight basis. It was also lower in general than was found in the sugar-maple tree. Only in about 20 per cent of all the present analyses does the concentration of total sugars equal one per cent of the fresh weight. The concentration ran quite low during the first growing season. During the second season it was somewhat higher throughout the season, and the main root, trunk and first year branches, showed usually a higher concentration than the other parts. No consistent differences appeared between the heavily and lightly pruned trees. No significance can be attached to the differences in sugar concentration during the first and second years because of the large errors liable to be involved in dealing with very small amounts. The most importance is to be attached to the relatively low total amounts found at any time and the lack of seasonal fluctuation in concentration.

The starch showed, in contrast to the sugar, marked fluctuation during the two years, but the decline in concentration during the growing season did not reach so low a point during the second as during the first year. The distribution of starch during the dormant season followed that found in the apple and maple. During accumulation in the autumn the heaviest deposition was found in the roots, so that in the main and lateral roots the percentage of starch was from two to three times that in the trunk and branches. During the growing season the starch reserve of the roots usually underwent a greater decline than that in the trunk and branches. As with the sugars, no striking or consistent differences between heavily or lightly pruned trees appeared in the distribution or concentration of starch.

The hemicellulose content of the tissues did not show seasonal fluctuations comparable with those of starch in either the first or second year. Tottingham and associates (4) have suggested that hemicellulose serves to some extent as a reserve food in the apple tree. The conditions of hydrolysis used in the present work were less severe than those used in the work cited. One per cent Hcl was used instead of 1:10 dilution of concentrated Hcl, so that the hemicellulose fraction reported here probably represents a more easily hydrolizable portion of the tissues than that reported for apple wood. The methods of determination of this group of constituents of tissues are so uncertain that the data obtained must be viewed with caution. The reported data simply indicate that there is no present reason for considering hemicellulose as reserve carbohydrates in the apricot, and it is excluded in the following discussion.

The seasonal fluctuation of total reserve foods during the two years is shown in columns six and seven of Table I. While this

fluctuation does not appear to be uniform, due to the differences in size of the trees, yet it shows the same summer decline in the amount of reserves as is shown in terms of percentage of fresh weight. The true condition of the trees in relation to the reserve foods is better brought out by column eight which shows the percentage of the total tree weight contained as reserves. The decline in reserves during the growing season is here shown clearly. From four to five percent at the beginning of the first season it fell to about one per cent in May and remained near this value till August, then rose till in January it reached the high value of nine per cent. During the second year a similar course was followed but the summer decline was not so large as in the previous year. The decline shown from January to March suggests a large consumption of materials during this period although actual growth was not large, but the data are too limited to be dependable. In comparing the heavily and lightly pruned trees during the second year, no consistent differences appear. In three cases of four the lightly pruned trees showed higher percentages of total reserves, but in the first and last cases the differences are probably too small to be of significance, and in the other two cases the results are opposed. The number of trees used is too small for dependence and the data are probably indicative only of variability among them.

The distribution of the total reserve foods within the individual tree is determined by their concentration in a given part and the bulk of that part. In column four is shown the percentage which the fresh weights of the different parts form of the individual tree weights. In column seven is shown similarly the percentage of the total carbohydrate reserves in the tree contained in each part. A study of column four shows that the root system usually comprises less than 50 per cent and more than 35 per cent of the total tree weight. In only five trees out of 19 did it exceed 50 per cent. These values are higher than would be found with trees on their own roots because in the present case the root system was one year older than the top. They are also probably higher than would be found for older budded trees. A comparison among themselves of the values found in column seven shows that during the dormant season the reserve carbohydrates in the root system comprised from 60 to 80 per cent of the total for each tree. During the first growing season the reserves in the root system fell as low as 30 per cent of the total reserves. During the second growing season the decline in root reserves was not so marked, the percentage remaining usually above 50. A comparison of columns four and seven shows that at all times except during the first growing season the percentage of total reserves found in the roots exceeded the percentage which the weight of the roots formed of the total tree weight. The excess was variable and bore no apparent relation to the seasonal activity of the trees. During the first growing season, on the contrary, the percentage of total reserves found in the root system fell below the percentage which the root system formed of the total tree weight. During this period the reserves

were actually more concentrated and totaled a greater amount in the trunk and branches than in the roots.

The data show clearly the preponderance of the root reserves for trees of these ages at all times, except during the first growing season. If to the root reserves are added the trunk reserves a still greater proportion of the total reserves is included, ranging from 100 per cent at the beginning to 63 per cent later with most of the values lying above 80 per cent. Turning to the remainder of the tree at the end of the first growing season it is found that but nine to 17 per cent of the total reserves of the trees occurred in the branches. At the end of the second year's growth there were formed in the second-year branches from seven to 19 per cent of the total reserves. From the standpoint of pruning this would appear to be of importance. If pruning were limited to the last season's growth and one-half of this by weight were removed it would result in a maximum loss of 9½ per cent of the reserves and an average loss of about six per cent per tree. This does not appear to be a very serious depletion of reserves. One-half the weight of the last season's branches would be very much more than one-half of the length of these branches, including the lateral branches, and would be rather severe pruning.

In comparing the lightly and heavily pruned tree with regard to subsequent pruning it must be considered that a large proportion of the tree's weight exists as last season's branches when the trees are more heavily pruned. At the end of the second year's growing season, of the four trees among which comparisons may be made, one lightly pruned tree bore 454 grams of second year branches, the other 523 grams, while one heavily pruned tree bore 899 and the other 712 grams. The total reserves in these branches in the above order were 21.6, 19.9, 29.6 and 23.1 grams. The percentages of reserves in this wood were respectively 4.9, 3.8, 3.3 and 3.1. The branches on the lightly pruned trees were somewhat higher in concentration of reserves, but not in proportion to their smaller total weights. Removing one-half of the reserves in the branches of the lightly pruned trees would have meant losses of 10.8 and 9.9 grams, while with the heavily pruned trees the losses would have been 14.8 and 11.5 grams. At the same time there would have been removed from the lightly pruned trees 227 and 267 grams and from the heavily pruned trees 450 and 356 grams of wood. Approximately twice as much wood would have been removed on the average from the heavily as from the lightly pruned trees and about 30 per cent more reserves.

In pruning by heading only terminal parts are removed. This usually includes at least the terminal halves of the main stems and most of the lateral branches. The distribution of the reserves within the branches then becomes of importance. In the above cases it is found that of the total reserves occurring in the second year branches, the percentages found in the terminal halves of the main stem and the laterals where present were 28, 49, 52 and 51. Removal of the laterals and terminal halves of the main stem would have removed no more than one-half of the reserves of the branches.

The total lengths of the wood of the second year branches, including the laterals, in these trees, were 1279, 2217, 3783 and 2462 cm., the last two being the heavily pruned trees. The percentages of total length contained in the laterals and terminal halves of the main stems are respectively 50, 78, 88 and 80. From the table it may be seen that the main stems contain by far the greater proportion of the reserves; in no case does more than about 20 per cent occur in the laterals. Of the reserves occurring in the main stems the percentages found in the terminal halves were 28, 25, 29 and 39. It is apparent that the principal reservoir of reserves in the branches would be left in pruning these trees by heading. In thinning, when entire branches were removed, the basal portion of the main stem would be lost. However, in pruning two sets of branches equally severely, one set by removing entire one-half the branches and the other by heading all the branches to one-half the length of the main stem and removing all the laterals, little or no difference would result in the effect on the reserve foods. The important feature in pruning, so far as reserves are concerned, appears to be not the length of wood removed or the point at which it is taken, but the total weight removed. Thinning may be fully as severe pruning in this respect as heading.

The spurs taken from the last two trees shown in the table totalled approximately the same weight The only significance attached to the data for these is that they show that the spurs do not differ in composition from adjoining tissues, and as a whole contain a very insignificant part of the tree's reserve carbohydrates.

Summary

1. The total sugar, starch and hemicellulose content of the apricot tree during the first and second years is shown.

2. Hemicellulose did not appear to function as a reserve carbohydrate in the apricot

3. The sugar content of the tissues was generally lower than in the apple and maple trees, and showed no significant seasonal fluctuations.

4. The starch content of the tissues was about the same as in the apple, but much higher than in the maple.

5. Starch was usually two or three times as abundant in the roots as in the trunk and branches

6. Large depletion of starch occurred during the growing season. This depletion was especially heavy in the roots during the first year.

7. The proportion of the total reserves in the tree which were found in the root system was especially high except during the first growing season when the greater proportion was found in the trunk and branches.

8 No consistent differences were found between lightly and heavily pruned trees in abundance or distribution of reserves.

9. Spurs were found to have the same composition as adjoining parts and to contain a very low fraction of the total tree reserves.

TABLE I

Results of Chemical Analyses of the Apricot Tree

1	2	3	4	5	6	7	8	9	10	11	12
Date removed	Part of tree	Fresh weight of parts	Percentage of tree weight	Percentage of dry matter	Total reserve foods, sugar plus starch		Total reserves as percentage of total tree weight	Carbohydrates, percentage of fresh weight			
					Weight in grams	Percent of total in tree		Total sugars	Starch	Sugars plus starch	Hemicellulose
February 15, 1921	Lateral roots	53	11.9	47.0	2.2	14.2	—	0.0	4.2	4.2	5.8
	Main root	209	47.0	50.8	11.5	76.7	—	0.0	5.5	5.5	7.2
	Trunk	183	42.1	54.2	1.3	8.6	—	0.3	0.4	0.7	7.3
	Totals	445	—	—	15.0	—	4.2	—	—	—	—
March 19, 1921	Lateral roots	42	12.0	42.0	2.5	14.4	—	0.1	5.8	5.9	3.9
	Main root	151	43.0	47.0	11.0	63.6	—	0.1	7.2	7.3	5.6
	Trunk	158	45.0	49.9	3.8	22.0	—	0.2	2.2	2.4	5.7
	Totals	351	—	—	17.3	—	4.9	—	—	—	—
April 18, 1921	Lateral roots	55	13.6	39.9	1.4	13.5	—	0.4	2.2	2.6	4.3
	Main root	165	41.0	39.8	5.9	56.7	—	0.5	3.1	3.6	5.1
	Trunk	183	45.4	48.6	3.1	29.8	—	0.2	1.5	1.7	5.9
	Totals	403	—	—	10.4	—	2.6	—	—	—	—
May 6, 1921	Lateral roots	39	16.4	39.0	0.3	15.8	—	0.1	0.7	0.8	3.6
	Main root	79	33.2	40.0	0.5	26.3	—	trace	0.6	0.6	5.0
	Trunk	120	50.4	42.3	1.1	57.9	—	0.2	0.7	0.9	4.9
	Totals	238	—	—	1.9	—	0.8				

June 2, 1921	Lateral roots	38	10.4	36.8	0.3	8.1	—	trace	0.8	0.8	3.2
	Main root	123	33.5	41.2	1.1	29.7	—	0.1	0.8	0.9	4.8
	Trunk	178	48.5	49.9	2.1	56.8	—	0.1	1.1	1.2	5.0
	First year branches	28	7.6	29.0	0.2	5.4	—	trace	0.7	0.7	2.5
	Totals	367	—	—	3.7	—	1.0	—	—	—	—
July 2, 1921	Lateral roots	26	12.1	39.0	0.1	4.4	—	0.1	0.3	0.4	3.3
	Main root	54	25.1	40.0	0.6	26.1	—	trace	1.1	1.1	4.0
	Trunk	108	50.2	49.7	1.4	60.8	—	0.2	1.1	1.3	4.4
	First year branches	27	12.6	31.1	0.2	8.7	—	trace	0.7	0.7	2.6
	Totals	215	—	—	2 3	—	1.0	—	—	—	—
August 6, 1921	Lateral roots	55	8.1	37.1	1.6	8.9	—	trace	2.9	2.9	2.7
	Main roots	216	31.8	44.8	8.0	44.2	—	0.1	3.6	3.7	4.8
	Trunk	241	35.5	49.0	6.0	33.1	—	0.2	2.3	2.5	5.4
	First year branches	167	24.6	40.7	2.5	13.8	—	0.2	1.3	1.5	4.1
	Totals	679	—	—	18.1	—	2.7	—	—	—	—
September 8, 1921	Lateral roots	52	8.3	37.5	0.8	5.9	—	trace	1.5	1.5	3.5
	Main root	172	27.3	43.1	4.8	35.3	—	0.1	2.7	2.8	4.7
	Trunk	249	39.6	45.8	5.7	41.9	—	0.1	2.2	2.3	5.6
	First year branches	156	24.8	39.9	2.3	16.9	—	0.1	1.4	1.5	4.9
	Totals	629	—	—	13.6	—	2.2	—	—	—	—

TABLE I (*Continued*)

Results of Chemical Analyses of the Apricot Tree

1	2	3	4	5	6	7	8	9	10	11	12
Date removed	Part of tree	Fresh weight of parts	Percentage of tree weight	Percentage of dry matter	Total reserve foods, sugar plus starch		Total reserves as percentage of total tree weight	Carbohydrates, percentage of fresh weight			
					Weight in grams	Percent of total in tree		Total sugars	Starch	Sugars plus starch	Hemicellulose
October 29, 1921	Lateral roots	63	12.5	50.1	4.9	19.5	—	trace	7.8	7.8	6.5
	Main root	160	31.8	50.3	13.1	52.2	—	trace	8.2	8.2	6.5
	Trunk	136	27.1	52.0	4.5	17.9	—	0.1	3.2	3.3	6.9
	First year branches	144	28.6	44.7	2.6	10.4	—	0.1	1.7	1.8	5.7
	Totals	503	—	—	25.1	—	5.0	—	—	—	—
January 3, 1922	Lateral roots	129	16.5	52.3	18.8	26.0	—	0.8	13.8	14.6	2.8
	Main root	224	28.6	54.5	30.7	42.6	—	0.6	13.1	13.7	1.6
	Trunk	202	25.8	52.5	10.1	14.1	—	0.9	4.1	5.0	2.4
	First year branches	228	29.1	49.8	12.5	17.3	—	0.5	5.0	5.5	3.4
	Totals	783	—	—	72.1	—	9.2	—	—	—	—
March 13, 1922	Lateral roots	218	22.0	45.2	13.3	27.1	—	0.3	5.8	6.1	1.1
	Main root	184	18.6	49.5	16.6	33.8	—	0.4	8.6	9.0	2.7
	Trunk	299	30.2	51.2	10.8	22.0	—	0.8	2.8	3.6	2.4
	First year branches	290	29.2	47.0	8.4	17.1	—	0.8	2.1	2.9	1.8
	Totals	991	—	—	49.1	—	5.0	—	—	—	—

May 4, 1922 Lightly pruned	Lateral roots	259	24.8	39.5	12.2	39.6	—	0.6	4.1	4.7	1.3
	Main root	310	29.6	47.0	8.4	27.3	—	0.9	1.9	2.8	1.8
	Trunk	266	25.4	48.2	5.3	17.2	—	0.7	1.3	2.0	1.4
	First year branches	212	20.2	44.2	4.9	15.9	—	0.6	1.7	2.3	3.2
	Totals	1047	—	—	30.8	—	2.9	—	—	—	—
May 4, 1922 Heavily pruned	Lateral roots	185	23.8	37.3	4.3	23.4	—	0.7	1.6	2.3	1.2
	Main root	300	38.5	42.6	8.1	44.0	—	1.3	1.4	2.7	2.7
	Trunk	252	32.4	46.7	5.3	28.8	—	1.0	1.1	2.1	3.0
	First year branches	41	5.3	41.5	0.7	3.8	—	0.3	1.4	1.7	2.2
	Totals	778	—	—	18.4	—	2.4	—	—	—	—
June 15, 1922 Lightly pruned	Lateral roots	132	15.0	33.5	2.1	8.4	—	0.2	1.4	1.6	3.7
	Main root	178	20.2	41.3	12.8	51.2	—	0.3	6.9	7.2	5.0
	Trunk	219	25.0	46.0	3.9	15.6	—	0.3	1.5	1.8	5.7
	First year branches	280	31.8	39.8	4.8	19.2	—	0.4	1.3	1.7	5.2
	Second year branches	70	8.0	34.0	1.4	5.6	—	0.4	1.6	2.0	3.9
	Totals	879	—	—	25.00	—	2.8	—	—	—	—
June 15, 1922 Heavily pruned	Lateral roots } Main root }	212	26.3	46.5	18.9	55.9	—	0.7	8.2	8.9	5.3
	Trunk	316	39.2	48.8	8.5	25.2	—	0.8	1.9	2.7	6.6
	First year branches	186	23.1	49.0	5.2	15.4	—	0.8	2.0	2.8	6.2
	Second year branches	92	11.4	38.3	1.2	3.5	—	0.5	0.8	1.3	5.0
	Totals	806	—	—	33.8	—	4.1	—	—	—	—

TABLE I (*Continued*)

Results of Chemical Analyses of the Apricot Tree

1	2	3	4	5	6	7	8	9	10	11	12
Date removed	Part of tree	Fresh weight of parts	Percentage of tree weight	Percentage of dry matter	Total reserve foods sugar plus starch		Total reserves as percentage of total tree weight	Carbohydrates, percentage of fresh weight			
					Weight in grams	Percent of total in tree		Total sugars	Starch	Sugars plus starch	Hemi-cellulose
September 2, 1922 Lightly pruned	Lateral roots	368	14.5	50.5	28.0	17.0	—	trace	7.6	7.6	3.3
	Main root	547	21.5	53.4	33.9	20.4	—	0.3	5.9	6.2	5.2
	Trunk	690	27.2	51.2	43.5	26.2	—	1.1	5.2	6.3	2.7
	First year branches	580	22.8	51.7	38.9	23.4	—	1.1	5.6	6.7	2.9
	Second year branches										
	Basal halves	225	8.9	48.1	13.7	8.3	—	0.5	5.4	5.9	3.3
	Terminal halves	129	5.1	47.6	7.9	4.7	—	0.5	5.6	6.1	2.0
	Totals	2539	—	—	165.9	—	6.6	—	—	—	—
September 4, 1922 Heavily pruned	Lateral roots	562	18.0	42.6	23.0	14.9	—	0.5	3.6	4.1	3.2
	Main root	661	21.2	51.1	44.9	29.0	—	1.4	5.4	6.8	4.3
	Trunk	753	24.2	51.5	43.7	28.2	—	1.6	4.2	5.8	3.3
	First year branches	237	7.6	49.2	13.5	8.7	—	1.4	4.3	5.7	3.3
	Second year branches										
	Basal halves	428	13.8	49.8	14.2	9.2	—	0.4	2.9	3.3	4.1
	Terminal halves	168	5.4	47.7	5.7	3.7	—	0.6	2.8	3.4	3.7
	Laterals	303	9.8	48.8	9.7	6.3	—	0.4	2.8	3.2	3.2
	Totals	3112	—	—	154.7	—	5.0	—	—	—	—

January 5, 1923 Lightly pruned	Lateral roots										
	Small	314	7.5	46.6	34.5	11.7	—	0.5	10.5	11.0	2.4
	Large	824	19.6	50.0	89.0	30.2	—	0.6	10.2	10.8	3.9
	Main root	740	17.6	54.3	75.5	25.6	—	1.3	8.9	10.2	5.4
	Trunk	988	23.7	52.9	43.4	14.8	—	1.4	3.0	4.4	4.9
	First year branches	769	18.3	51.4	31.5	10.7	—	1.3	2.8	4.1	2.8
	Second year branches										
	Basal halves	266	6.4	49.3	10.1	3.4	—	0.7	3.1	3.8	2.3
	Terminal halves	99	2.4	48.0	3.6	1.2	—	0.7	3.0	3.7	2.1
	Laterals	158	3.8	49.0	6.2	2.1	—	0.7	3.2	3.9	2.0
	Spurs	30	0.7	48.5	0.8	0.3	—	0.6	2.2	2.8	2.0
	Totals	4188	—	—	294.6	—	7.0	—	—	—	—
January 4, 1923 Heavily pruned	Lateral roots										
	Small	279	8.3	44.3	27.6	12.4	—	0.6	9.3	9.9	2.0
	Large	667	19.7	49.8	72.0	32.4	—	1.3	9.5	10.8	2.1
	Main root	612	18.1	54.2	50.7	22.8	—	1.2	7.1	8.3	3.2
	Trunk	717	21.2	51.7	35.1	15.8	—	1.6	3.3	4.9	4.0
	First year branches	358	10.6	52.2	12.9	5.8	—	1.8	1.8	3.6	3.7
	Second year branches										
	Basal halves	397	11.7	49.9	11.1	5.0	—	0.6	2.2	2.8	4.4
	Terminal halves	142	4.2	48.8	7.0	3.1	—	1.0	3.9	4.9	2.8
	Laterals	173	5.1	48.0	5.0	2.2	—	1.1	1.8	2.9	3.0
	Spurs	36	1.1	48.4	1.1	0.5	—	1.1	1.9	3.0	3.7
	Totals	3381	—	—	222.5	—	6.7	—	—	—	—

10. The relation of these data to various pruning practices is discussed.

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The Course of Pollen Tube Growth in the Apple

By J. H. BEAUMONT, *University Farm, St. Paul, Minn.*

This address will be published in the Minnesota Plant Science Series.

Notes on Pruning and Training Concord Grapes in Illinois

By A. S. COLBY and A. C. VOGELE, *University of Illinois, Urbana, Ill.*

Although Concord grapes are grown commercially in several localized areas in Illinois no particular system of training has been consistently followed. It was thought advisable to determine experimentally what system was best adapted to Illinois conditions and to learn something of the relation between the growth and fruitfulness of the vine and the method of training.

Pruning and training studies have been carried on for two years using 610 Concord grape vines planted ten feet square on the University Farm. The vineyard is situated on the eastern slope of a recessional morain characteristic of the early Wisconsin glaciation. The soil is brown silt loam of morainal type, merging into a black clay spot at the base of the slope.

Four standard systems of training were followed: the Kniffin, the Munson, the Fan, and the Chautauqua. Five classes of vines were chosen, those pruned to 16–25, 26–35, 36–45, 46–55, and 56–65 buds respectively. The small dormant bud at the base of the cane was counted in all cases. Slightly less than one-half of the 244 vines

trained to the Kniffin system were modified to the double trunk system, while the remainder were single trunk vines. Slight environmental differences in soil and site were overcome by a systematic distribution of the vines bearing different numbers of buds, throughout the entire vineyard.

Table I shows the average yield in pounds for the past two years, the number of vines in each class, and the range in yield from the poorest producer to the highest yielding vine for each class in each system of training. From a two year average it would seem that vines trained to the Chautauqua system were most desirable from the standpoint of productiveness. There is, however, an added expense incurred for time required for summer tying when the Chautauqua system is used.

From the standpoint of convenience and economy in handling and the probability of easy renewal for the longest period of years the grapes trained to the Kniffin system show to best advantage. Taken as a whole the vines trained to the Kniffin system and pruned to 46–55 buds gave yields as high as could fairly be expected, consistent with size of individual bunch and berry and attractiveness of fruit. Vines pruned and trained to more than 55 buds, while resulting in higher yields for the two years concerned, produced bunches and berries of smaller size. Records taken during succeeding years will be of value in studying the effects of too light and too heavy pruning. The range in pounds is considerable in some instances. This results from the use of vines of different degrees of vigor, etc., and shows the need of large numbers of vines in a pruning experiment to as far as possible eliminate chances of error.

The table also shows in the case of extremely poor producers (i. e. lower ranging vines) that the number of buds left on a vine is of less consequence than on other more productive vines. However, a low producing vine in the 56–65 bud class might have been a better producer if less buds had been left.

Again, a poor producer is often a poor producer because a poor selection of canes was made in the actual pruning of the vine. It was found in this work that the most fruitful type of cane was one whose internodes were from 10 to 15 times as long as the diameter of the canes. The greatest diameter and length of internode of every cane on the 244 Kniffin vines were recorded, the diameter in every case being taken midway between the third and fourth node, at its widest part.

Partridge (1) has produced data which show that the diameter of the individual cane is related to its fruitfulness. He shows that the highest yields were secured from canes of one-quarter inch in diameter. Later Partridge (2) states that in ordinary pruning practice it is not always possible to choose canes of exactly proper diameter. He suggests that in such cases it is better to use canes a little larger rather than a little smaller. Partridge bases his recommendations on measurements made between the fifth and sixth nodes. We took measurements between the third and fourth nodes as stated above, since shorter canes were necessarily left in the class pruned to leave 16 to

TABLE I

Average Yields and Range in Pounds of Grapes Trained to Different Systems Leaving Varying Numbers of Buds.

	16-25 buds		26-35 buds		36-45 buds		46-55 buds		56-65 buds		66-75 buds	
Year	1923	1924	1923	1924	1923	1924	1923	1924	1923	1924	1923	1924
Kniffin	7.94	6.17	13.44	8.00	21.42	12.37	24.64	15.24	27.29	19.09	—	—
Number of Vines	51	22	57	51	54	69	47	54	6	39	—	—
Range in pounds	2–17¼	1–12	5¾–24	2½–17	11½–33¾	1–22	15¼–38¼	4–25½	22½–34	8–30½	—	—
Munson	—	—	12.50	12.52	14.59	15.90	18.69	18.27	20.82	19.23	—	—
Number of Vines	—	—	23	21	22	32	24	33	25	30		
Range in pounds	—	—	6–29	4–21	5–23	11–24	5–31	9–30	11–33	8–25	—	—
Fan	—	—	13.19	8.06	16.41	14.47	17.27	16.19	22.05	17.99	—	—
Number of Vines	—	—	26	30	37	34	30	31	22	24	—	—
Range in pounds	—	—	5–23	3–15	9–32	6–32	7–28	8–27	15–33	9–34	—	—
Chautauqua	—	—	12.35	9.58	16.00	13.75	21.14	15.50	25.42	17.90	28.38	19.00
Number of Vines	—	—	20	24	17	28	21	24	21	22	24	22
Range in pounds	—	—	4–18	4–19	7–24	7–22	11–30	6–27	13–37	11–26	9–37	11–23

25 buds under the Kniffin system of training. In general, however, our records confirm the results secured by Partridge.

Canes can readily be classified according to vegetative vigor from these two measurements. Canes less than 0.60 of a centimeter in diameter were invariably poor producers, and weakly vegetative. Frequently canes in this class also had short internodes. Canes of 0.60 to 0.85 cm. in diameter were the most fruitful canes. Canes from 0.85 to 1.00 cm. in diameter were inclined to be less fruitful and large, thick canes whose diameters exceeded 1.00 cm. were invariably poor producers with long internodes and consequently fewer leaves and low carbohydrate supply.

The small buds close to the base of each cane were invariably dormant or produced a fruitless cane, in fact only a few clusters of fruit were produced from this basal bud from over 950 canes.

Our results confirm Shrader's (3) work at Maryland where he groups canes of similar diameters into three classes according to their fruiting capacity.

Further investigations are in progress with reference to other growth and fruiting relations such as are involved in various systems of training and pruning and their effect on vines in connection with winter injury.

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2. N. L. Partridge. "Pruning the Concord Grape," American Fruit Grower, Jan. 1925: 5, pp. 17–18.

3. A. L. Shrader. "Growth Studies of the Concord Grape," Proc. Amer. Soc. Hort. Sci. Rpt., 1923, pp. 116–122.

Great Plains Section of the A. S. H. S.

By W. R. Leslie, *Secretary, Experiment Station, Morden, Manitoba.*

THE annual meeting in 1924 was held in Manitoba August 11, 12, and 13, with a subsequent side trip August 14, and 15. The convention opened at noon in Kildonan Park, Winnipeg, where the city provided the luncheon.

The afternoon was spent in making a tour by auto of the vegetable market garden district to the north of Winnipeg, visiting the Kildonan Cannery, and inspecting the fine gardens of a number of excellent suburban properties.

In the evening a basket picnic was supplied by the Charleswood Horticultural Society in Assiniboine Park. Thereafter, the presentation of the Carter Medal, awarded to the person making the most outstanding contribution to Canadian horticultural development during the preceding year, was made by Hon. W. R. Motherwell, Dominion Minister of Agriculture, to Mrs. Stevenson, in token of the

excellent accomplishments achieved in prairie horticulture by her husband, the late A. P. Stevenson.

A short business session took place at the Manitoba Agricultural College on the morning of the 12th. Progress reports were delivered by Prof. Norman M. Ross, Forestry Nursery Station, Indian Head, Saskatchewan, and by Dr. R. Moore, Fort Frances, Ontario. The officers elected for 1925 are, President, Prof. Norman M. Ross, Chief of the Tree Planting Division, Indian Head, Saskatchewan; Vice-President, Prof. W. G. Brierley, University Farm, St. Paul, Minnesota; Secretary, Prof. A. F. Yaeger, Agriculture College, Fargo, North Dakota. The state selected for 1925 meetings is NorthDakota.

After a survey of the extensive College plantations, the members motored south-westward to Pine Grove Nursery, the home of A. P. Stevenson and Sons, near Morden. Visitors were surprised at the quality and productivity of the sour cherry seedlings. Apple and plum trees of many varieties were in good bearing.

The feature of the evening entertainment was a couple of illustrated addresses by Prof. W. F. Broderick, Manitoba Agricultural College, and by Mr. Geo. Batho, Department of Agriculture, Winnipeg, on "Beauty Spots of Manitoba." Many lantern slides were shown. The meetings welcomed the superintendents, with their assistants, from the prairie branch farms of the Dominion Experimental Farms System, and Prof. E. S. Archibald, Director, and several divisional chiefs from Ottawa, who had convened at Morden for their annual conference.

An early start by auto was made the morning of the 13th. The itinerary was through a typical Mennonite village and then about and through the horticultural plantings at the Morden Dominion Experimental Station. This Station has 100 acres devoted to horticultural work. Here is found the largest fruit plantation on the Canadian prairies, and one of the widest collections of hardy tree fruits in Canada.

After the complimentary luncheon in the Morden park, a life membership to the Manitoba Horticultural Forestry Association was presented to Mr. J. J. Ring by Prof. W. T. Macoun, Dominion Horticulturist. Mr. Ring is an ardent grower of trees, fruits, vegetables and flowers on his farm, near Crystal City, Manitoba. This concluded the definite program.

Side trips to the northern parts of the province had been arranged, and a Pullman car full of members leaving Winnipeg that evening arrived at Dauphin early in the morning of the 14th. The towns and countryside were traversed in automobiles.

The afternoon was spent at Boughen's Nursery, near Valley River. Mr. Boughen has an excellent assortment of hardy plums and crab apples, as well as many small fruits. His successes proved a considerable surprise to more southerly visitors.

The 15th was spent in the Roblin and Dropmore areas and much time was reserved for the trial grounds of Mr. F. L. Skinner, private plant breeder near Dropmore. Mr. Skinner has the most complete collection of hardy conifers to be found on the northern prairies.

He has produced some valuable hardy hybrid roses, and some promising new lilac hybrids and plums. His work with hardy herbaceous perennials is extensive.

The previous visit by the Society to Manitoba and the Canadian prairies was in 1919.

Report of the Committee on Cooperation with the National Research Council

By H. D. HOOKER, Jr., *Chairman, University of Missouri, Columbia, Mo.*

SINCE 1920 the American Society for Horticultural Science has had a Committee of Cooperation with the National Research Council. At the Chicago meeting of the Society a project was undertaken, the object of which as originally stated was:

"To assemble and prepare for publication in the form of a Report brief descriptions and suggestive notes and explanations of the more important economic aboreal plants now growing in the principal collections of the United States and Canada, including the Arnold Arboretum; the collections at the New York Experiment Station, Geneva; the Rochester, New York, Public Parks; the Ottawa, Canada, station and branch stations throughout western Canada; the collections of the United States Department of Agriculture at Mandan, North Dakota, and Chico, California; and other growing collections, national and state, where cooperation may be secured. To prepare the descriptive notes and suggestions in such fashion that they will furnish plant breeders and horticultural workers with specific information as to the location of the living material for study, the age and size of the plants, the blooming and fruiting periods, special characteristics such as disease and insect resistance, cold resistance, drought resistance, etc."

At present, attention is being confined to fruits and nuts and the need for descriptions has been largely eliminated by the publication of Bailey's "Manual of Cultivated Plants." The committee reports that it has obtained lists of the fruits and nuts growing in the Arnold Arboretum; in the collections at the New York Experiment Station, Geneva; in the Rochester, New York, Public Parks; in the Brooklyn Botanical Gardens; in the collections at Ottawa and at Guelph, Canada; and at the Michigan and Missouri Experiment Stations. Lists have also been received of the collection of figs at the Forkner Fig Gardens at Fresno, California, and of the Collection of Pyrus at Talent, Oregon. Assurances have been received that lists of the collections at the Minnesota and South Dakota Experiment Stations, and at Riverside, California, will be supplied. The report of the committee would be of little value if it did not include the collections of

the United States Department of Agriculture. During the past year, the committee received the following statement from Mr. Roland McKee: "We are working at the present time upon permanent currant plantings at our stations, and, when the information is available, I will be glad to advise you regarding fruits and nuts, which I understand are the only classes you are interested in."

The committee, therefore, has definite assurances that its work can be completed, although it may be some time before the lists of the Department of Agriculture collections have been compiled. In the meantime, lists of collections that have not been submitted will be welcomed.

The finished report will be one of the most comprehensive lists of the fruits and nuts of this country and should be of great value to horticultural workers. The lists already submitted include 865 different species, botanical varieties and hybrids of deciduous fruits and nuts alone.

NUT AND FRUIT GENERA

11	Acanthopanax	2	Diospyros	93	Ribes
18	Aesculus	3	Elaegnus	4	Rosa
3	Amelanchier	9	Fagus	79	Rubus
1	Asimina	5	Fragaria	12	Sambucus
28	Carya	1	Gaylussacia	2	Shepherdia
8	Castanea	13	Juglans	56	Sorbus
24	Chaenomeles	1	Maclura	14	Vaccinium
1	Citrus	104	Malus	40	Viburnum
23	Cornus	6	Morus	38	Vitis
16	Corylus	200	Prunus	1	Zizyphus
1	Cydonia	50	Pyrus	—	
				865	Total

Dinner and Social Evening

Ninety-eight members and friends attended the Society dinner at the Harrington Hotel. This is much the largest dinner group we have ever had. Many of the younger members and some of the older ones had never before had the opportunity of joining in the pleasures of the annual dinner.

After the meal was finished chairs were pushed back and through ths courtesy of the Chilean Nitrate Agencies a six reel film named "White Magic" was shown. This film was taken by the Nitrate Agencies and has not yet been released. It is supposed to show in an allegorical way the magic power of nitrogen to awaken life and vigor in fruit trees. The magic wand was wielded by a maiden dressed in white who caused the trees to burst forth into leaf and bloom. Potash and phosphorous were represented by other maidens who could not awaken the trees completely without the aid of Miss Nitrogen. Many

of the scenes were taken in the orchards of Maryland, Pennsylvania, West Virginia, and other states where orchard fertilizer experiments are being conducted by the experiment stations. There is much to commend in this film, but at present it is too fearfully long and there is too much repetition of certain scenes.

After the film was shown President Dorsey turned the entertainment of the crowd over to Peggy McCue who first demonstrated the need of a cover crop on some of the bald headed and near bald headed members. Other features of the evening were jokes, stories, recitations, cross word puzzles and other stunts participated in by such artists as McHatton, Howard, Wessels, McClintock, Dorsey, Blair and Auchter. The actors brought forth continuous shouts of mirth and side splitting laughter. The din was so great that Blair closed the street windows for fear of disturbing the quiet beats of the peaceful Washington police.

Items of Business

Amendment to By-Laws

At the 1923 meeting an amendment to Section 5 of the By-Laws was offered changing the number of members of the program committee from seven to three. This amendment was adopted at the 1924 meeting.

Amendment Offered to By-Laws

The Secretary offered an amendment to Section 6 of the By-Laws to read "The annual dues of the Society shall be three dollars and fifty cents, or more."

Voluntary Donation to Botanical Abstracts

Although financial aid has been given to Botanical Abstracts, a considerable amount is still needed by the committee in charge and the Society was asked to arrange for the collection of a few hundred dollars in case it is needed. After some discussion a motion was passed requesting a voluntary donation of from one to five dollars from each member, the funds to be collected through the Secretary's office. If this donation is called for by Botanical Abstracts the Secretary will notify all members.

International Conference on Plant Science

The Society was asked to appoint a representative on the International Conference on Plant Science. President Dorsey appointed Dr. A. J. Heinicke as the Society's representative.

Report of the Committee on Resolutions

Resolved, That the members of the American Society for Horticultural Science extend to the officials of the Central High School of Washington, D. C., and to the various local committees, their appreciation of the efficient arrangements for the success of our meetings.

Be it Resolved, That we express to the Bausch and Lomb Optical Company our appreciation of the loan of lantern and translucent screen during the meeting.

Be it Resolved, That the thanks of the Society be extended the Chilean Nitrate Agencies for the privilege of seeing the film "White Magic" before its release to the public.

C. A. McCue,
H. R. Jones,
W. A. Ruth,
Committee.

Election of Officers

The nominating committee in making its report presented the names of H. C. Thompson and V. R. Gardner as candidates for the office of president. A ballot was taken and H. C. Thompson receiving a majority of the votes was declared nominated. Prof. Gardner immediately moved to make the nomination of Prof. Thompson unanimous. The motion carried. The Secretary was then instructed to cast the vote of the Society for the officers and committees whose names appear on page five of this report.

A M BURROWS

Obituary

Ambrose Matson Burroughs

Mr. A. M. Burroughs, Instructor in Horticulture at the University of Missouri, was killed in an automobile accident near Greenfield, Indiana, on September 8, 1924.

Mr. Burroughs was born at Columbus, New York, May 12, 1898. He attended the district schools in Gaines, New York, and high school at Albion, New York, from which he was graduated in 1914. Because of his high standing at the Albion high school, he was awarded the four year State scholarship at Cornell University. He entered Cornell University in the fall of 1915.

Before completing his course at Cornell University, he enlisted in the army air service, January 3, 1918. He was commissioned as second lieutenant and was on active flying duty until the time of his discharge from the service August 15, 1919. He reentered Cornell University in the fall of 1919, being graduated with a B. S. degree in June, 1920. Continuing his work at Cornell University as an assistant in the Department of Pomology, he received his M. S. degree in 1921. He was elected to Alpha Zeta and Sigma Xi.

In the fall of 1921, Mr. Burroughs went to the Marble Laboratory, Inc., Canton, Pennsylvania, where he was engaged in fruit storage research until the close of 1923. He then went to the University of Missouri as instructor in pomology and to carry on research work along pomological lines. He would soon have completed his work for the Ph.D., degree.

Although relatively young, Mr. Burroughs had made his influence felt, particularly in the field of pomological research. His published reports on fruit storage studies and on the use of oil sprays are real contributions to our horticultural research literature. His untimely death was a marked loss to American horticulture, particularly in the research field, as well as a great personal loss to his many friends.

Interment was at Ira cemetery, Cayuga Co., New York.

J. R. Magness.

MEMBERSHIP ROLL FOR 1924

ALDERMAN, W. H. .....University Farm, St. Paul, Minn.
ALLEN, F. W. ....University Farm, Davis, Calif.
ANTHONY, R. D. .... ..Experiment Station, State College, Pa.
AUCHTER, E. C. ....University of Maryland, College Park, Md.
AUSTIN, LLOYD ....University Farm, Davis, Calif.

BAILEY, J. S. ....Agricultural College, Amherst, Mass.
BAILEY, L. H. ....Ithaca, N. Y.
BAIRD, W. P. ....Northern Great Plains Field Station, Mandan, N.D.
BALCH, W. B. ... ...Agricultural College, Manhattan, Kans.
BALLARD, W. R. ....University of Maryland, College Park, Md.
BALLARD, W. S. ....U. S. Dept. Agr., Washington, D. C.
BARNETT, R. J. ....Agricultural College, Manhattan, Kans.
BARRON, LEONARD .....Garden City, N. Y.
BARSS, A. F. ....University of British Columbia, Vancouver, B. C.
BATCHELOR, L. D. .....Citrus Experiment Station, Riverside, Calif.
BEACH, F. H. ....Ohio State University, Columbus, Ohio
BEAL, A. C. ... ...Cornell University, Ithaca, N. Y.
BEATTIE, J. H. ....U. S. Dept. Agr., Washington, D. C.
BEATTIE, W. R. ....U. S. Dept. Agr., Washington, D. C.
BEAUMONT, J. H. ......University Farm, St. Paul, Minn.
BENNETT, J. P. ....University of California, Berkeley, Calif.
BIOLETTA, F. T. ....University of California, Berkeley, Calif.
BLAIR, J. C. .... University of Illinois, Urbana, Ill.
BLAIR, W. S. .... Experiment Station, Kentville, Nova Scotia.
BLAKE, M. A. .... Experiment Station, New Brunswick, N. J.
BOSWELL, V. R. .... . University of Maryland, College Park, Md.
BREGGER, J. T. .... . Lousiana, Mo.
BRIERLEY, W. G. ......University Farm, St. Paul, Minn.
BROWN, H. D. ....Purdue University, Lafayette, Ind.
BUCK, F. E. ....University of British Columbia, Vancouver, B. C.
BUNTING, T. R.........Macdonald College, Macdonald College P. O., Quebec, Canada.
BURKHOLDER, C. L. .. .Purdue University, Lafayette, Ind.
BURRELL, B. J. .... . University Farm, St. Paul, Minn.
BUSHNELL, J. W. ......Experiment Station, Wooster, Ohio
BURNSIDE, B. L. .... ..University of Maryland, College Park, Md.

CALDWELL, J. S. .... . U. S. Dept. Agr., Washington, D. C.
CAMERON, S. H. .... .. University of California, Berkeley, Calif.
CARPENTER, C. C. .....Syracuse University, Syracuse, N. Y.
CARRICK, D. B. ....Cornell University, Ithaca, N. Y.
CHANDLER, W. H. .....University of California, Berkeley, Calif.
CHITTENDEN, L. W. ....N. Y. State School of Agriculture, Cobleskill, N. Y
CLARK, C. F. ....U. S. Dept. Agr., Washington, D. C.
CLARK, J. H. .... Experiment Station, New Brunswick, N. J.
CLOSE, C. P. ....U. S. Dept. Agr., Washington, D. C.
COIT, J. E. ....1880 Linda Vista Ave., Pasadena, Calif.
COLBY, A. S. .... University of Illinois, Urbana, Ill.
COLE, W. R. ....Agricultural College, Amherst, Mass.
CONDIT, I. J. ..... . .California Peach and Fig Growers Associatio Fresno, Calif.
CONNORS, C. H. ....Experiment Station, New Brunswick, N. J.
COOPER, J. R. ....University of Arkansas, Fayetteville, Ark.
CORBETT, L. C. ....U. S. Dept. Agr., Washington, D. C.
CRANDALL, C. S. ....University of Illinois, Urbana, Ill.
CRANE, H. L. ....University of West Virginia, Morgantown, W. Va.
CRIST, J. W. ....Agricultural College, East Lansing, Mich.

CROW, J. W.	Simcoe, Ontario, Canada
CULLINAN, F. P.	Purdue University, Lafayette, Ind.
DALY, P. M.	Central Experimental Farm, Ottawa, Canada
DANIELS, F. P.	University Farm, St. Paul, Minn.
DARROW, G. M.	U. S. Dept. Agr., Washington, D. C.
DARROW, W. H.	Agricultural College, Storrs, Conn.
DAVIS, M. B.	Dominion Experimental Farm, Ottawa, Canada
DAVIS, V. H.	State Department of Agriculture, Columbus, Ohio
DEARING, CHARLES	Willard, N. C.
DETJEN, L. R.	University of Delaware, Newark, Del.
DICKSON, G. H.	Vineland Station, Ontario, Canada
DIKEMAN, R. C.	School of Agriculture for Women, Ambler, Pa.
DORNER, H. B.	University of Illinois, Urbana, Ill.
DORSEY, M. J.	West Virginia University, Morgantown, W. Va.
DRAIN, B. D.	Agricultural College, Amherst, Mass.
DRINKARD, Jr., A. W.	Experiment Station, Blacksburg, Va.
DUDLEY, F. N.	5 Manitou Ave., Poughkeepsie, N. Y.
DURST, C. E.	53 West Jackson Blvd., Chicago, Ill.
DUTTON, W. C.	Agricultural College, East Lansing, Mich.
EDMINSTER, A. F.	Spring Brook Farm, East Freetown Mass.
EDMOND, J. B.	Agricultural College, East Lansing, Mich.
ELLENWOOD, C. W.	Experiment Station, Wooster, Ohio
ERWIN, A. T.	Iowa State College, Ames, Iowa.
EUSTACE, H. J.	Curtis Publishing Co., San Francisco, Calif.
FAGAN, F. N.	Experiment Station, State College, Pa.
FARLEY, A. J.	Rutgers College, New Brunswick, N. J.
FAROUT, F. W.	Missouri Fruit Station, Mountain Grove, Mo.
FISHER, D. F.	Wenatchee, Wash.
FLETCHER, S. W.	Pennsylvania State College, State College, Pa.
FLOYD, B. F.	Wilson and Toomer Fertilizer Co., Jacksonville, Fla.
FLOYD, W. L.	University of Florida, Gainesville, Fla.
FRENCH, A. P.	Agricultural College, Amherst, Mass.
FRENCH, W. F.	North High School, Worcester, Mass.
FROST, H. B.	Citrus Experiment Station, Riverside, Calif.
GARDNER, A. K.	University of Maine, Orono, Me.
GARDNER, J. S.	University of Kentucky, Lexington, Ky.
GARDNER, M. E.	Clemson Agricultural College, Clemson College, S. C.
GARDNER, V. R.	Agricultural College, East Lansing, Mich.
GARNER, C. A.	U. S. Dept. Agr., Washington, D. C.
GEISE, F. W.	University of Maryland, College Park, Md.
GLADWIN, F. E.	Experiment Station, Fredonia, N. Y.
GOULD, H. P.	U. S. Dept. Agr., Washington, D. C.
GOURLEY, J. H.	Experiment Station, Wooster, O.
GRAY, G. F.	University of Delaware, Newark, Del.
GRAVES, G. W.	State Teachers & Junior College, Fresno, Calif.
GREENE, L.	Purdue University, Lafayette, Ind.
GRIFFITHS, DAVID	U. S. Dept. Agr., Washington, D. C.
HALLER, M. H.	U. S. Dept. Agr., Washington, D. C.
HANSEN, N. E.	Agricultural College, Brookings, S. D.
HARLEY, C. P.	University of Maryland, College Park, Md.
HARTMAN, HENRY	Oregon Agricultural College, Corvallis, Ore.
HARVEY, E. M.	Oregon Agricultural College, Corvallis, Ore.
HEDRICK, U. P.	Experiment Station, Geneva, N. Y.
HEINICKE, A. J.	Cornell University, Ithaca, N. Y.
HENDRICKSON, A. H.	Deciduous Fruit Station, Mountain View, Calif.
HEPLER, J. R.	Agricultural College, Durham, N. H.
HERRICK, R. S.	State House, Des Moines, Iowa

HIGGINS, J. E. .... Los Banos College, Laguna, P. I.
HILDRETH, A. C. .... University Farm, St. Paul, Minn.
HOFFMANN, G. P. .... College of Agriculture, Clemson College, S. C.
HOFFMAN, I. C. .... Purdue University, Lafayette, Ind.
HOLLAND, C. S. .... Ohio State University, Columbus, Ohio.
HOLLISTER, S. P. ..... Agricultural College, Storrs, Conn.
HOLMES, F. S. .... Experiment Station, College Park, Md.
HOOKER, Jr., H. D. .... University of Missouri, Columbia, Mo.
HOPPERT, E. H. .... University of Nebraska, Lincoln, Neb.
HOSHINO, YUZO .... The Tohoku Imperial University, Sapporo, Japan
HOWARD, W. L. .... University Farm, Davis, Calif.
HOWE, G. H. .... Experiment Station, Geneva, New York
HOWLETT, F. S. .... Cornell University, Ithaca, N. Y.
HUBER, H. F. ...... Experiment Station, New Brunswick, N. J.
HUELSEN, W. A. ...... University of Illinois, Urbana, Ill.
HUFFINGTON, J. M. .... College of Agriculture, Clemson College, S. C.
HUSMANN, F. L. ...... Second and Seminary Streets, Napa, Calif.
HUSMANN, G. C. .... U. S. Dept. Agr., Washington, D. C.

ISBELL, C. L. .... Alabama Polytechnic Institute, Auburn, Ala.

JENKINS. E. W. .... University of Vermont, Burlington, Vt.
JOHNSON, T. C. .... Virginia Truck Experiment Station, Norfolk, Va.
JOHNSTON, S. M. ...... Experiment Station, South Haven, Mich.
JONES, H. A. .... University Farm School, Davis, Calif.

KEENE, P. L. .... Agricultural College, Brookings, S. D.
KIMBALL, D. A. ..... Agricultural College, Guelph, Ontario, Canada
KNAPP, H. B. .... Schoharie County School of Agriculture, Cobleskill, N. Y.
KNOWLTON, H. E. ..... West Virginia University, Morgantown, W. Va.
KRAUS, E. J. .... University of Wisconsin, Madison, Wis.
KRAYBILL, H. R. ...... Boyce Thompson Institute, Yonkers, N. Y.

LAVOIE, J. H. .... Department of Agriculture, Quebec, Canada
LESLIE, W. R. .... Experiment Station, Morden, Manitoba.
LEWIS, I. P. .... Experiment Station, Marietta, Ohio
LINCOLN, F. B. .... Clarks Summit, Pa.
LOCKLIN, H. D. .... Western Washington Experiment Station, Puyallup, Wash.
LOMBARD, P. M. .... U. S. Dept. Agr., Washington, D. C.
LOMMEL, W. E. .... Purdue University, Lafayette, Ind.
LONG, C. L. .... Agricultural College, Corvallis, Ore.
LOOMIS, W. E. .... Cornell University, Ithaca, N. Y.
LUCE, W. A. .... Wenatchee, Wash.

MACDANIELS, L. H. .... Cornell University, Ithaca, N. Y.
MACGILLIVRAY, J. H. ... University of Wisconsin, Madison, Wis.
MCCLINTOCK, J. A. .... Experiment Station, Knoxville, Tenn.
MCCORMICK, A. C. ..... Husum, Wash.
MCCUE, C. A. .... Experiment Station, Newark, Del.
MCHATTON, T. H. ..... State College of Agriculture, Athens, Ga.
MCKAY, H. M. .... State College of Agriculture, Athens, Ga.
MACK, W. B. .... Agricultural College, Amherst, Mass.
MACKINTOSH, R. S. .... University Farm, St. Paul, Minn.
MACOUN, W. T. .... Central Experimental Farm, Ottawa, Canada
MAGILL, W. W. .... University of Kentucky, Lexington, Ky.
MAGRUDER, ROY .... Experiment Station, Wooster, Ohio
MAGNESS, J. R. .... U. S. Dept. Agr., Washington, D. C.
MANN, A. J. .... Experiment Station, Summerland, B. C.
MARBLE, L. M. .... Canton, Pa.
MARKELL, E. L. .... American Fruit Growers, Inc., Sanford, Fla.
MARKWELL, E. D. ..... Agricultural and Mechanical College, Stillwater, Okla.
MARSHALL, R. E. ...... Agricultural College, East Lansing, Mich.

MASON, A. F.	University of New Jersey, New Brunswick, N. J.
MATHEWS, C. W.	Agricultural College, Lexington, Ky.
MATTHEWS, C. D.	State Department of Agriculture, Raleigh, N. C.
MERRILL, M. C.	U. S. Dept. Agr., Washington, D. C.
MILLS, H. S.	Cornell University, Ithaca, N. Y.
MILWARD, J. G.	University of Wisconsin, Madison, Wis.
MOORE, J. G.	University of Wisconsin, Madison, Wis.
MORRIS, L. S.	Brigham Young University, Provo, Utah
MORRIS, O. M.	Experiment Station, Pullman, Wash.
MOTZ, F. A.	Virginia Polytechnic Institute, Blacksburg, Va.
MULFORD, F. L.	U. S. Dept. Agr., Washington, D. C.
MURNEEK, A. E.	University of Missouri, Columbia, Mo.
MUSSER, A. M.	College of Agriculture, Clemson College, S. C.
MYERS, C. E.	Experiment Station, State College, Pa.
NAMIKAWA, ISAWO	Kyoto Imperial University, Kyoto, Japan
NICHOLS, H. E.	Iowa State College, Ames, Iowa
NIGHTINGALE, G. F.	University of Wisconsin, Madison, Wis.
OLNEY, A. J.	Experiment Station, Lexington, Ky.
OSKAMP, JOSEPH	Cornell University, Ithaca, N. Y.
OVERHOLSER, E. L.	University of California, Berkeley, Calif.
OVERLEY, F. L.	Agricultural College, Pullman, Wash.
PADDOCK, W.	Ohio State University, Columbus, Ohio
PAGE, E. M.	University of Missouri, Columbia, Mo.
PAINTER, J. H.	University of Maryland, College Park, Md.
PALMER, E. F.	Vineland Station, Ontario, Canada
PALMER, R. C.	Experiment Station, Summerland, B. C.
PARTRIDGE, N. L.	Agricultural College, East Lansing, Mich.
PATTERSON, C. F.	Saskatoon, Saskatchewan, Canada
PELTON, W. C.	University of Delaware, Newark, Del.
PERRY, D. P.	U. S. Dept. Agr., Washington, D. C.
PHILLIPS, H. A.	State Teachers College, Warrensburg, Mo.
PICKETT, B. S.	Iowa State College, Ames, Iowa
POTTER, G. F.	Agricultural College, Durham, N. H.
PRICE, H. L.	Experiment Station, Blacksburg, Va.
PROEBSTING, E. L.	University Farm, Davis, Calif.
QUINN, J. T.	University of Missouri, Columbia, Mo.
RADSPINNER, W. A.	College of Agriculture, Raleigh, N. C.
RALEIGH, G. J.	Agricultural College, Amherst, Mass.
RANDALL, G. O.	State College of Agriculture, Raleigh, N. C.
RAWL, E. H.	Aiken, S. C.
REED, H. J.	Experiment Station, Lafayette, Ind.
REED, C. A.	U. S. Dept. Agr., Washington, D. C.
REES, R. W.	521 Cutler Building, Rochester, N. Y.
REHDER, ALFRED	Arnold Arboretum, Jamaica Plain, Mass.
RICHEY, H. W.	Iowa State College, Ames, Iowa
RIES, V. H.	Purdue University, Lafayette, Ind.
RITCHIE, T. F.	Central Experimental Farm, Ottawa, Canada
ROBBINS, W. W.	University Farm, Davis, Calif.
ROBERTS, R. H.	University of Wisconsin, Madison, Wis.
ROFKAR, W. F.	Experiment Station, Wooster, Ohio
ROSA, Jr., J. T.	University Farm, Davis, Calif.
ROSS, HUGH	Miller School, Va.
RUEF, J. U.	Iowa State College, Ames, Iowa
SAX, KARL	University of Maine, Orono, Me.
SAYRE, C. B.	University of Illinois, Urbana, Ill.
SCHERMERHORN, L. C.	Experiment Station, New Brunswick, N. J.

SCHNECK, H. W. .... Cornell University, Ithaca, N. Y.
SCHRADER, A. L. .... University of Maryland, College Park, Md.
SCHUSTER, C. E. .... Agricultural College, Corvallis, Ore.
SEARS, F. C. .... Agricultural College, Amherst, Mass.
SEVY, H. P. .... University of West Virginia, Morgantown, W. Va.
SHAW, J. K. .... Agricultural College, Amherst, Mass.
SHAW, P. J. .... Agricultural College, Truro, N. S.
SHIMA, Y. .... Kuroishi Agricultural Experiment Station, Aomoriken, Japan
SHOEMAKER, D. N. ..... U. S. Dept. Agr., Washington, D. C.
SHOEMAKER, J. S. ...... University Farm, St. Paul, Minn.
SLATE, G. L. .... Experiment Station, Geneva, N. Y.
SMITH, JR., A. G. ...... Virginia Polytechnic Institute, Blacksburg, Va.
SNYDER, ELMER ...... Hotel Willard, Fresno, Calif.
SNYDER, R. S. .... Pennsylvania State College, State College, Pa.
STAFFORD, I. B. .... Syracuse University, Syracuse, N. Y.
STRONG, W. J. .... Vineland Station, Ontario, Canada
STUART, WILLIAM ...... U. S. Dept. Agr., Washington, D. C.
SWARTWOUT, H. G. .... University of Missouri, Columbia, Mo.
SWEETSER, H. P. ...... University of Maine, Orono, Me.
SWINGLE, C. F. .... U. S. Dept. Agr., Washington, D. C.

TALBERT, T. J. .... University of Missouri, Columbia, Mo.
TAPLEY, W. T. .... Pennsylvania State College, State College, Pa.
TAWSE, W. J. .... Macdonald College, Macdonald College, Quebec, Canada
TAYLOR, R. H. .... 3931 Eye St., Sacramento, Calif.
THAYER, PAUL .... Pennsylvania State College, State College, Pa.
THOMPSON, H. C. ...... Cornell University, Ithaca, N. Y.
TIEDJENS, V. A. .... Market Gardners' Field Station, Lexington, Mass.
TOMPKINS, C. M. ...... Agricultural College, Fort Collins, Colo.
TUFTS, W. P. .... University Farm School, Davis, Calif.
TUKEY, H. B. .... Experiment Station, Geneva, N. Y.

UNDERWOOD, F. O. ..... Cornell University, Ithaca, N. Y.

VANDERVORT, H. S. .... West Virginia University, Morgantown, W. Va.
VAN METER, R. A. ..... Agricultural College, Amherst, Mass.
VIERHELLER, A. F. ..... University of Maryland, College Park, Md.
VINCENT, C. L. .... State College of Washington, Pullman, Wash.
VINSON, C. G. .... Experiment Station, Wooster, Ohio
VOLZ, E. C. .... Iowa State College, Ames, Iowa

WAGONER, C. C. .... Virginia Polytechnic Institute, Blacksburg, Va.
WAID, C. W. .... Ohio Farm Bureau Federation, Columbus, Ohio
WALKER, JOHN .... University Farm, St. Paul, Minn.
WARING, J. H. .... Pennsylvania State College, State College, Pa.
WATTS, R. L. .... Experiment Station, State College, Pa.
WAUGH, F. A. .... Agricultural College, Amherst, Mass.
WEBBER, H. J. .... University of California, Berkeley, Calif.
WELLINGTON, J. W. ... U. S. Dept. Agr., Washington, D. C.
WELLINGTON, R. .... Experiment Station, Geneva, N. Y.
WELLS, H. M. .... Graham Horticultural Experiment Station, Grand Rapids, Mich.
WENTWORTH, S. W. .... Agricultural College, Durham, N. H.
WERNER, H. O. .... University of Nebraska, Lincoln, Neb.
WESSELS, P. H. .... Cornell University, Ithaca, N. Y.
WESTOVER, K. C. ...... West Virginia University, Morgantown, W. Va.
WHITEHOUSE, W. E. .... University of Maryland, College Park, Md.
WHITMIRE, J. S. .... University of Illinois, Urbana, Ill.

WIGGIN, W. W. ....University of Maine, Orono, Me.
WIGGINS, C. C. ....University of Nebraska, Lincoln, Neb.
WILCOX, A. N. ....University Farm, St. Paul, Minn.
WILLIS, H. L. ....University of Wyoming, Laramie, Wyo.
WINTER, J. D. ....University Farm, St. Paul, Minn.
WOOD, M. N. ....409 Native Sons Hall, Sacramento, Calif.
WOODBURY, C. G. ......National Canners' Association, Washington, D. C.
WORK, PAUL ....Cornell University, Ithaca, N. Y.

YEAGER, A. F. ....Agricultural College, Fargo, N. D.
YERGER, H. R. ....R. R. 3, Apollo, Pa.
YERKES, G. E. ....U. S. Dept. Agr., Washington, D. C.
YOUNG, W. J. ....Route 4, Albany, Ala.

ZIMMERLEY, H. H. .....Virginia Truck Experiment Station, Norfolk, Va.
ZIMMERMAN, P. W. .....University of Maryland, College Park, Md.
ZUBER, N. D. ....Little Rock, Ark.

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PROCEEDINGS

of the

American Society

for

Horticultural Science

1925

TWENTY-SECOND ANNUAL MEETING

H. C THOMPSON

PROCEEDINGS

OF THE

AMERICAN SOCIETY

FOR

HORTICULTURAL SCIENCE

1925

Twenty-Second Annual Meeting,
Kansas City, Mo.

December 29, 30 and 31, 1925

Published by the Society
Edited by the Secretary, C. P. Close,
College Park, Maryland

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CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Any person who has a baccalaureate degree and holds an official position in an agricultural college, experiment station, or Federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, and a Secretary-Treasurer, who, together with the chairmen of the standing committees, shall constitute a Council to act upon all applications for membership. There shall also be an Assistant Secretary. These officers shall be elected annually by ballot.

ARTICLE VI

This Constitution may be amended by two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS

SECTION 1. The President and other officers shall perform the usual duties of their respective offices. The President shall also deliver an address at each regular meeting.

SEC. 2. There shall be a Committee on Nominations consisting of five (5) members, who shall be nominated and elected by ballot at each regular meeting of the Society. It shall be the duty of this committee, at the following meeting, to suggest to the Society names for officers, referees, and members of committees for the ensuing year.†

SEC. 3. There shall be an Executive Committee, consisting of three (3) members and the President and the Secretary, ex-officio. This committee shall perform the usual duties devolving upon such committee.

SEC. 4. The Committee on Nominations shall nominate referees and alternates upon special subjects of investigation or instruction, which may be referred to its consideration by the Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned them, and to report the present status of the same.

SEC. 5. There shall be a Committee on Program, consisting of three (3) members, of which the Secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society.

SEC. 6. The annual dues of the Society shall be three dollars and fifty cents.

SEC. 7. Ten members of the Society shall constitute a quorum.

*The Constitution and By-Laws as amended from time to time.
†Since 1913 two lists of candidates have been required.

TREASURER'S REPORT FOR 1925

Voucher No. 1925		Cr.		
	Jan. 6	Stamps		$ 2.00
(1)	Jan. 12	Record book		1.40
(2)	Jan. 14	Expressage on 1924 report manuscript to the printer, Geneva, N. Y.		.62
	Jan. 17	Stamps		1.00
(3)	Jan. 23	W. F. Humphrey, Geneva, N. Y.		
		1500 Letterheads	$ 7.50	
		2250 Envelopes	12.25	
		Postage	.70	
				20.45
	Jan. 26	Stamps		1.00
	Jan. 31	Stamps		5.00
(4)	Feb. 7	Maurice Joyce Engraving Co., Washington, D. C. 2 copper halftones		8.18
(5)	Feb. 7	Charles G. Stoll & Co., Inc., Washington, D. C. 1000 No. 70 Columbia Clasp Envelopes		14.80
	Feb. 20	Stamps		1.00
	Mch. 5	Stamps		1.00
	Apr. 6	Stamps		2.00
(6)	Apr. 6	Expressage on annual reports from Geneva, N. Y.		1.65
	Apr. 9	Stamps		1.00
	Apr. 13	Telegram to W. F. Humphrey, Geneva, N. Y.		.55
(7)	Apr. 18	Freight on 1924 reports from printer in Geneva, N. Y.		2.64
	Apr. 20	Postage on 1924 reports		12.21
	Apr. 21	Stamps		1.00
	Apr. 27	Stamps		1.00
	Apr. 30	Stamps		1.00
	May 1	Stamps		1.00
	May 6	Stamps		2.00
	May 15	Stamps		1.00
(8)	May 15	W. F. Humphrey, Geneva, N. Y.		
		35 membership separates for 1924	$ 4.50	
		Postage on do	.12	
		450 reports of 1924—404 pages at $2.05 per page	828.20	
		6 half tone inserts at $4.50 each	27.00	
		Extra composition on J. P. Bennett's paper	2.50	
		Author's alterations	28.35	
		Wrapping and mailing	4.00	
		Wrapping paper	1.05	
		Postage on reports mailed to members by the printer	25.08	
				920.80
	May 25	Stamps		1.00
	June 10	Stamps		1.00
	June 11	Stamps		4.00
	July 9	Stamps		1.00
	July 10	Stamps		1.00
	Sept. 8	Stamps		1.00
	Sept. 11	Stamps		1.00
	Oct. 14	Stamps		1.00
	Oct. 20	Stamps		3.00
	Oct. 23	Stamps		1.00
	Nov. 2	Stamps		1.00
	Nov. 14	Stamps		5.00

(9) Nov. 18	W. F. Humphrey, Geneva, N. Y. Printing 450 programs for the 1925 meeting....$19.00 Postage on do. .27		19.27
Nov. 28	Stamps		1.00
(10) Dec. 26	Horticultural Department, University of Maryland, College Park, Maryland. 250 2c stamps used by program committee..		5.00
(11) Dec. 26	Edythe Beard, College Park, Md., stenographic work, stencils and mimeograph paper for preparing abstracts of the 1925 meeting		18.50
(12) Dec. 26	The University Press, College Park, Md. Printing 250 dinner tickets.		2.50
	To Balance		899.06
	Total.		$1,970.63

1925 Dr.

	By Balance	$890.33
Feb. 9	University of Maryland, College Park, Md. Reports 1921, 1922	5.00
Feb. 17	Lloyd Austin, Davis, Calif. Reports 1914, 1915, 1916, 1917, 1918, 1919, 1920, 1921	12.00
Feb. 20	Pennsylvania State College, State College, Pa. Reports 1922, 1923.....	5.00
Mch. 6	The American News Co., New York, N. Y. Report 1923..	2.50
Mch. 7	L. M. Marble, Canton, Pa. Report 1922......	2.50
Mch. 18	G. E. Stechert & Co., New York, N. Y. Reports 1921, 1922, 1923	7.50
April 6	University of Chicago, Chicago, Ill. Reports 1905, 1906, 1908 & 9, 1910, 1914, 1915, 1916, 1917, 1918, 1919, 1920, 1921, 1922, 1923..	22.00
April 6	Prof. Niels Erbjerg, Blangsted, Pr. Odense, Denmark. Report 1924.	2.50
April 6	Edgar H. Wells, New York, N. Y. Report 1922....	2.50
April 21	C. Lewis, New York, N. Y. Report 1924.......	2.50
April 21	Franklin Square Subscription Agency, New York, N. Y. Report..	2.50
April 25	The Roessler & Hasslacher Chemical Co., Perth Amboy, N. J. Report 1924.	2.50
April 28	W. F. Faxon Co., Boston, Mass. 2 reports 1924......	5.00
April 29	Cornell University Library, Ithaca, N. Y. Report 1924....	2.50
April 30	G. E. Stechert & Co., New York, N. Y. 2 reports for 1924 .	5.00
April 30	His Majesty's Stationery Office, London, England. Report 1923	2.50
May 4	Roy Larsen, Wenatchee, Wash. Report 1924...........	2.50
May 4	Seattle Public Library, Seattle, Wash. Report 1924......	2.50
May 4	E. L. Probsting, Davis, Calif. Reports 1905, 1906, 1910, 1914, 1915, 1916, 1917, 1918..	9.50
May 4	Massachusetts Agricultural College, Amherst, Mass. Report 1924..	2.50
May 4	Thorborn & Abbott, Ottawa, Canada. Report 1924.	2.50
May 4	University of Maine, Orono, Maine. Report 1924........	2.50
May 4	Franklin Square Subcription Agency. New York, N. Y. Report 1924..	2.50
May 4	L. M. MacDaniels, Ithaca, N. Y. Reports 1923, 1924.....	5.00
May 5	L. W. Corbett, Ithaca, N. Y. Report 1924.............	2.50
May 6	Virginia Agricultural Experiment Station, Blacksburg, Va. Report 1924	2.50
May 11	Brooklyn Institute of Arts & Sciences, Brooklyn, N. Y. Report 1924	2.50
May 12	Pennsylvania State College, State College, Pa. Report 1924	2.50

May	12	Missouri Botanical Garden, St. Louis, Mo. Report 1924	2.50
May	12	Arnold Arboretum, Jamaica Plain, Mass. Report 1924	2.50
May	12	G. E. Stechert & Co., New York, N. Y. Report 1924	2.50
May	13	Oregon State Agricultural College, Corvallis, Oregon. Report 1924	2.50
May	14	University of Nebraska, Lincoln, Neb Report 1924	2.50
May	14	University of Minnesota, St. Paul, Minn. Report 1924	2.50
May	16	Rudulph Florin, Stockholm 50, Sweden. Report 1924	2.50
May	19	State College of Washington, Pullman, Wash. Report 1924	2.50
May	20	Prof. A. M. Sprenger, Wageningen, Holland. Report 1924	2.50
May	21	Georgia Experiment Station, Experiment, Ga. Report 1924	2.50
May	25	University of Wisconsin, Madison, Wis Report 1924	2.50
May	28	University of Vermont, Burlington, Vt. Report 1924	2.50
May	28	Massachusetts Horticultural Society, Boston, Mass Report 1924	2.50
May	28	Stanford University, Stanford University, Calif. Report 1924	2.50
May	28	Cornell University Library, Ithaca, N. Y. Report 1924	2.50
June	1	Purdue University, LaFayette, Ind. Report 1924	2.50
June	1	Georgia State College of Agriculture, Athens, Ga. Report 1924	2.50
June	1	W. H. Nixon, San Carlos, Calif Reports 1923, 1924	5.00
June	5	Utah Agricultural College, Logan, Utah. Report 1924	2.50
June	8	State Agricultural College, Fort Collins, Colo. Report 1924	2.50
June	8	Prof Y. Asami, Tokyo, Japan Report 1924	2.50
June	13	Ontario Agricultural College, Guelph, Canada Report 1924	2.50
June	13	University of California, Berkeley, Calif. 3 reports 1924	7.50
July	6	Ohio Agricultural Experiment Station, Wooster, Ohio. Report 1924	2.50
July	6	A. E. Fisher, Mechanicsburg, Ohio. Report 1924	2.50
July	6	Kentucky Agricultural Experiment Station, Lexington, Ky. Report 1924	2.50
July	6	E. Steiger & Co., New York, N. Y. Reports 1918, 1919, 1921, 1922, 1923, 1924	13.00
July	6	University of Missouri, Columbia, Mo. Report 1924	2.50
July	6	Wheldon & Wesley, Ltd., London, England. Reports 1923, 1924	5.00
July	9	O. S. H. Reinecke, Stellenbosch, South Africa. Reports 1923, 1924	4.80
July	13	His Majesty's Stationery Office, London, England. Reports 1922, 1924	5.00
July	20	Oklahoma A. & M. College, Stillwater, Okla. Report 1924	2.50
July	22	Lee M. Hutchins, Washington, D. C. Report 1924	2.50
July	24	B. Login & Son, New York, N. Y. Reports 1919, 1920, 1921, 1922, 1923, 1924	13.50
July	27	New York Agricultural Experiment Station, Geneva, N. Y. Report 1924	2.50
July	30	Iowa State College, Ames, Iowa. Report 1924	2.50
Sept.	8	State Department of Agriculture, Harrisburg, Pa. Report 1924	2.50
Sept.	10	University of West Virginia, Morgantown, W. Va. Report 1924	2.50
Sept.	10	R. L. Barrett, Monett, Mo. Report 1924	2.50
Sept.	11	H. P. Traub, St. Paul, Minn. Report 1924	2.50
Oct.	13	University of Delaware, Newark, Del. Reports 1915, 1917	2.50
Oct.	13	University of Arizona, Tucson, Ariz. Report 1924	2.50
Oct.	22	Wm. Dawson & Sons, Ltd., London, England. 2 sets each of reports for 1920, 1921, 1922, 1923, 1924	25.00
Nov.	2	E. J. Kraus, Madison, Wis. Reports 1921, 1922	5.00
Nov.	9	Ontario Agricultural College, Guelph, Ontario, Canada. Report 1922	2.50

Nov. 27	Alabama Polytechnic Institute, Auburn, Ala. Reports 1903 & 4, 1905, 1906, 1908 & 9, 1910, 1914, 1915, 1916, 1917, 1918, 1919, 1920, 1921, 1922	20.50
Dec. 15	Herman Goldberger, Boston, Mass. Reports 1924, 1925	5.00
Dec. 15	Licinio Cappelli, Bologna, Italy. Reports 1924, 1925	5.00
Dec. 28	Moore-Cottrell Subscription Agencies, North Cohocton, Mass. Report 1924	2.50
	Dues collected since 1924 meeting	750.00
	Total	$1,970.63

Respectfully submitted,
C. P. CLOSE, *Treasurer.*

The auditing committee reported that it had examined the accounts of the Treasurer and found them to be correct.

M. J. DORSEY
B. S. PICKETT
T. H. MCHATTON
Auditing Committee.

Annual Meeting at Kansas City, Missouri

December 29, 30, and 31, 1925

THE attendance at Kansas City was not quite so large as was expected, but about 70 members were present. The absence of eastern men was particularly noticeable. There was no one from the New England States, nor from Pennsylvania, New Jersey or Delaware, and only 1 from New York and 2 from Maryland and none from Canada. Most of the attendance was from the central, southern, and mid-western states. California sent 4 members and Idaho sent 1. Many of the "old timers" were absent. Five of the charter members were on hand.

President Thompson presided at the general sessions and at the vegetable sections and "made it snappy." The 80 papers listed and 3 extra ones made a crowded program, but many papers whose authors were not present were read by title only. The meeting broke into sections one day and in the absence of the vice-president, Messrs. Alderman and Dorsey took turns in presiding at the fruit section.

There was considerable time for discussion, in fact in only a few instances was the discussion limited.

In point of program, in point of discussion, in point of substance of the addresses, and in point of all around good fellowship, the members felt that this was one of the best meetings we have ever held. There was not much of a preliminary nature reported on as was the case at the Washington meeting in 1924. There was a very great deal of deep plant chemical and plant physiological matter presented which easily equals anything the plant chemists and plant physiologists have to offer.

Our place of meeting in the building of the Kansas City Athletic Club was one of the best we have ever had.

Some of the things acted upon will be of interest to members who did not attend. The 1926 meeting in Philadelphia will last 4 days. Titles of papers for that meeting should be sent to the Program Committee by October 1 and abstracts of not more than 200 words by December 1. One session will probably be an invitation program. The American Society of Plant Physiologists will be invited to hold a joint program with us during one-half day or a whole day. A committee of 5 will be appointed to investigate the possibility of improving and perhaps unifying methods of horticultural research. To meet the increased cost of printing a very large report and of general society expenses the annual dues were raised to $3.50 beginning January 1, 1926.

The Secretary had fully decided to give up the office of Secretary-Treasurer, but was finally persuaded to continue "during good behaviour in office."

A Question of Professional Ethics

By S. W. Fletcher, *Pennsylvania State College, State College, Pa.*

ONE of the most valuable assets of a college horticulturist among his constituents—the commercial horticulturists of his state—is a reputation for impartial judgment. They like to feel that he is not swayed by any consideration except the truth, as he sees it; that when they ask his opinion on cultural problems they may expect to receive a conservative and unbiased reply. We should strive to merit and to safeguard this confidence.

A recent occurrence will serve to point the moral to this short tale. A prominent nursery firm discovers a promising new variety of apple. With much preliminary beating of the publicity drum—justified, no doubt, from a commercial point of view—a big meeting is held to view the marvel. Fruit growers and professional horticulturists come from every quarter of the country. Speeches are made. In the enthusiasm of the moment some of the professors make very laudatory remarks about the novelty. They are apt to regret these remarks a little later when they appear as part of highly seasoned advertising matter in which nursery trees of the new variety are offered for sale at high prices. What is even more embarrassing, some of the professional men attend the meeting at the expense of the nurseryman and this fact is common knowledge among fruit growers. Is it likely that the reputation for unbiased judgment of these men personally, and of college horticulturists generally, will be enhanced by this occurrence?

I hasten to add that there is no question whatever in my own mind but that these men—my associates in the professional field—will not be influenced in their future judgments in the slightest degree by the circumstances of this meeting. Nor do I charge the nursery firm with anything more than indiscretion, in that it has carried legitimate advertising too far. Unfortunately, however, the public may make a more unfavorable interpretation. Already I have heard fruit growers express rather caustic criticism of this meeting and especially of the connection of professional horticulturists with the advertising matter growing out of it.

To avoid even the appearance of evil is a scriptural injunction that we would do well to heed.

Pruning and Fertilizing Young Apple Trees at Planting

By H. B. Tukey, *New York State Agricultural Experiment Station, Geneva, N. Y.*

INTRODUCTION

THIS report is of a preliminary nature, dealing with but one phase of the fertilizer and pruning tests with different horticultural fruits of different ages which are being conducted in the Hudson River Valley by the New York State Agricultural Experiment Station. The soils of eastern New York are lower in fertility than those of western New York. Hudson River Valley soils, for example, are formed from slates and shales and are strongly acid, in contrast to the heavier limestone soils of western New York upon which most of the fruit investigations in New York State have been conducted.

The Problem of Fertilizers

Under these different conditions an entire set of new problems presents itself, chief among which are the responses to fertilizers of fruit crops grown on soils of low fertility. Accordingly, one of the first problems has been concerned with fertilizing apple trees of different ages, and for the test with young trees a parcel of land was selected which is admittedly perhaps the "poorest" from the standpoint of fertility of any available, classified as Hoosic coarse sand.

Previous work in western New York has shown no response of apple trees to applications of natural or artificial fertilizers when under a system of clean cultivation and cover cropping. Likewise nursery stock has failed to respond to fertilizer treatments. On the other hand the feeling among growers in the Hudson River Valley has been that fertilizer applications in general have resulted in quite marked responses, and in some unpublished work, the first season's test with French crab nursery stock gave a large increase in growth whenever nitrogenous fertilizers were used. Yet the young experimental orchard of two-year-old trees has shown no response after two years of clean cultivation and cover cropping.

It was felt, therefore, that since units the size of lead pencils, as in the case of the French crab stock, apparently responded to nitrogenous fertilizers and yet the two-year-old trees did not, that the question might be one of the *size* of the materials used, a small unit responding where a large one would not. And so large and small one-year-old trees, and two-year-old trees, were used in the tests.

In addition complaints had been received from time to time that in previous years young trees that had been fertilized with a quickly available nitrogenous fertilizer had sometimes failed to start and sometimes died later in the season. With this point in mind tests were included designed to ascertain whether the amount, or the place of application, was the cause of the injury.

Plan and Procedure

Seven rows of nine trees each were planted on the square 12½ feet apart, on a level uniform Hoosic coarse sand which had lain fallow for 15 years, and which had been plowed and kept clean cultivated without cropping the previous season. This soil type is deep, open, and low in fertility. Lying fallow it grows no strong sod. Each row but the seventh consisted of 3 one-year-old Rome Beauty trees, 3 feet in height; 2 large one-year-old Rome Beauty trees, 5 feet in height; 3 large one-year-old Baldwin trees, 6 feet in height, and 1 first class two-year-old Rome Beauty tree. In the seventh row the 2 Baldwin trees were omitted. The Rome Beauty trees were all secured from a local nursery, while the Baldwin trees were procured from Oregon.

The quickly available nitrogenous fertilizer was nitrate of soda, and the treatments were as follows:

Row 1. One-half pound applied in a circle well back from the trees, between 30 and 40 inches, just as the buds began to show green.

Row 2. One-half pound placed in the bottom of the holes when the trees were planted.

Row 3 One-half pound applied in a circle close to the tree, between two and eight inches, but not in contact, just as the buds began to show green.

Row 4. Nothing.

Row 5. One pound applied close to the trees as in row 3.

Row 6. Two pounds applied close to the trees as in row 3.

Row 7. Eight pounds applied close to the trees as in row 3.

The trees were headed at 30 inches for the small Rome Beauty trees, 50 inches for the large Rome Beauty trees, and 60 inches for the Baldwin trees. The area was kept free from weeds of any kind by frequent cultivation until the first of August, attendant almost entirely upon rains. That is, after each heavy rain it was necessary to break the thin tight crust that forms on this soil and which seems to stop growth immediately it is formed. Six cultivations were given in all during the season, and 3 sprayings were made with lime-sulfur, arsenate of lead, and nicotine sulphate.

Measurements of trunk diameter in 32nds of an inch were made 12 inches above the ground when the trees were planted and were again made in early November when growth had ceased. The total new growth was measured in inches at the same time.

Effect of Application in Contact With The Roots

All of the trees in all of the rows started into growth nicely, including those which had received nitrate of soda in the tree hole in contact with the roots. On May 20, however, the leaves of these trees were shrivelling as though burned with a spray and later dropped, although the leaves on the trees in the other rows appeared normal. At the end of the season all the Rome Beauty trees in this row—large and small one-year trees, and the two-year tree—were dead,

while the large one-year-old Baldwin trees had recovered sufficiently, late in the season, to put out a weak second lot of foliage.

Effect of Application Close to the Trees

On May 28 it was observed that the trees which had received one-half, 1, 2, or 8 pounds of fertilizer close to the trees, but not in contact with them, were not as vigorous as the unfertilized row or the row to which the application had been made well back from the trees, yet they were making satisfactory growth and without the other rows for comparison would have been considered as doing fairly well.

The early part of August brought several heavy rains and on August 20 the foliage on all of the trees but one of those receiving 8 pounds to the tree, had suddenly turned brown as though burned, exactly as had the foliage of the trees which had received fertilizer in the tree hole at planting. Within a few days the leaves had dropped and new foliage was pushing out.

A week later the trees receiving the next smaller amount of fertilizer, namely two pounds to the tree, began to show signs of the same typical tip-burning although it never progressed to a point where defoliation occurred. By September 8, on the next row, receiving 1 pound to the tree, browning had also appeared, while the row receiving one-half pound to the tree gave signs at no time of more than a very slight burning and which would normally have passed unnoticed, excepting for the striking performances already discussed of some of the other trees in the planting.

Effect of No Application and Application Back From the Trees

At no time was there any tip-burning on either the row receiving no fertilizer or on the row which received one-half pound 30 to 40 inches back from the trees. Both rows held green vigorous foliage throughout the season and were outstandingly superior to the rows receiving fertilizer close to the trees, or in contact with the roots. To the eye there was no difference between these 2 in color, size, or vigor of the foliage, though the row receiving no fertilizer seemed to begin dropping its foliage 4 days to a week earlier than the row which received one-half pound well back from the trees.

Response of Different Size and Age of Trees

Where there was any injury or tip-burning it always appeared first on the two-year old Rome Beauty trees, next on the small one-year-old Rome Beauty trees, next on the large one-year Rome Beauty trees, and finally on the large one-year Baldwin trees. Any recovery occurred in the reverse order, the large one-year-old Baldwin trees first, the large one-year Rome Beauty trees second, the small one-year Rome Beauty trees third, and the two-year Rome Beauty trees last. In every case the most vigorous trees were least injured and recovered most promptly, and so on down to the last two-year Rome Beauty trees which appeared less vigorous than any of the

others and were correspondingly the first to show injury and the last to recover. The only divergence from these effects was to be found in one one-year-old Rome Beauty tree receiving 8 pounds of fertilizer close to the tree which exhibited no outward injury whatsoever. That the fertilizer was applied was evident throughout the season by the dark ring of soil about the tree.

MEASUREMENTS

The figures given in the tables are self-explanatory and agree fairly well with the observations that have just been set forth, though because of the small numbers of individuals used and the variability of the trees it is a question whether the observations are not worth more than the measurements unless they be analyzed to not too fine degree.

TABLE I—INCREASE IN DIAMETER OF YOUNG APPLE TREES RECEIVING DIFFERENT AMOUNTS OF FERTILIZER IN DIFFERENT LOCATIONS ABOUT THE TREE AT PLANTING

Application	Where applied	Increase in Diameter in 32nds of an Inch				
		Small 1-year Rome Beauty	Two-year Rome Beauty	Large 1-year Rome Beauty	Large 1-year Baldwin	Average
	Number of trees	3	1	2	3	9
None		17.0	4.5	14.0	18.5	9.0
½ pound	Against roots*	-5.0	-2.0	-1.5	7.0	-.2
½ pound	Back from tree**	17.0	4.5	17.0	21.5	10.0
½ pound	Close to tree***	10.5	2.5	10.5	14.0	4.1
1 pound	Close to tree***	11.0	1.0	10.5	15.5	4.2
2 pounds	Close to tree***	8.0	2.0	7.5	16.0	3.9
8 pounds	Close to tree***	7.0	1.5	3.0	—	1.9

*Placed in the bottom of the tree hole.
**Applied in a circle between 24 and 36 inches back from the tree.
***Applied in a circle between 2 and 8 inches back from the tree.

TABLE II—TERMINAL GROWTH OF YOUNG APPLE TREES RECEIVING DIFFERENT AMOUNTS OF FERTILIZER IN DIFFERENT LOCATIONS ABOUT THE TREE AT PLANTING

Application	Where applied	Terminal growth in inches				
		Small 1-year Rome Beauty	Two-year Rome Beauty	Large 1-year Rome Beauty	Large 1-year Baldwin	Average
	Number of trees	3	1	2	3	9
None		301	150	300	260	112
½ pound	Against roots*	0	0	0	91	10
½ pound	Back from tree**	280	168	462	302	134
½ pound	Close to tree***	183	—	88	154	55
1 pound	Close to tree***	207	56	118	147	58
2 pounds	Close to tree***	161	71	118	136	54
8 pounds	Close to tree***	156	24	82	—	43

*Placed in the bottom of the tree hole.
**Applied in a circle between 24 and 36 inches back from the tree.
***Applied in a circle between 2 and 8 inches back from the tree.

For example, the outstanding points from Tables I and II are that the trees receiving either no fertilizer or one-half pound well back

from the trees, are grouped fairly close so far as increase in trunk diameters and total shoot growth are concerned. Rows receiving one-half 1, or 2 pounds close to the tree are grouped together; the row receiving 8 pounds is by itself; and finally stands the row receiving one-half pound against the roots. The observations, however, show the progressive injury from the larger to the smaller application and from the less vigorous to the more vigorous trees, facts which measurements have not revealed.

Again, young trees make the most of their growth early in the season and any abnormal cessation of growth which might be very evident to the eye is not given proportionate weight by measurements of total growth for the season. Nevertheless, the tables bear out in a general way the observations that have been recorded.

Discussion

It must be remembered that the soil on which this test was conducted is a deep, coarse sand or gravelly sandy loam, which allows water to pass through it quickly, so that it can be worked rather shortly after a moderate rain. At the same time a heavy rain compacts the soil and results in the formation of a crust on the surface which seems to effectively check growth unless it is broken by cultivation. Frequent, clean cultivations are, therefore, the rule.

Under such conditions of forced, frequent clean cultivation it is to be expected that nitrogenous fertilizers might not produce a response in trees to which they were applied. Furthermore, any quickly soluble salt, such as nitrate of soda, used in this test, must have a better opportunity to be lost by leaching or to be carried quickly through the soil by rains and water movement. In other words any harmful effects of quickly soluble fertilizers might be present on this type of soil and entirely lacking on others.

The wilted leaves of the trees which received a half-pound of nitrate of soda in the tree hole at planting probably point to a simple plasmolysis resulting in killing. Plasmolysis may or may not have been responsible where the burning, browning, or loss of leaves occurred in mid-summer to those trees which received applications close to the tree. If it is a case of plasmolysis perhaps the degrees of injury and recovery may be explained by sap concentrations at different periods in wood of different ages or vigor.

An interesting point, however, lies in the fact that excepting where the fertilizer was placed in contact with the roots, injury did not occur until mid-summer, over 90 days after application, even where only a half pound was applied.

This may suggest that even on soil types as open and subject to loss through leaching as this soil type is supposed to be, the fertilizer may not disappear as quickly as commonly believed.

The Problem of Pruning

Whether to cut back trees at planting or whether merely to thin out undesired branches has been a point of discussion in New York State. Some varieties seem better adapted to one style of pruning

than another and with Cortland, which is a new sort, it has not been tried. It may be well in passing to remark that Cortland has been receiving much attention in McIntosh circles as a later, firmer, better-hanging McIntosh type. It is the result of a cross between Ben Davis and McIntosh, produced in the breeding work at the State Experiment Station at Geneva. Accordingly this work takes on added interest because it deals with a variety which is a subject for discussion in itself.

Plan and Procedure

In a soil fertilizer test on the same light soil type previously referred to, 4 rows, 12 trees to the row, of semi-permanent two-year Cortland trees running across the fertilizer block, have been used for this test. Two rows were cut back at planting and 2 rows were thinned out, cutting back consisting of clipping back the lateral branches about one-half, and thinning out consisting of removing undesired laterals and doing no clipping to those that were left. The trunk diameters were measured in 32nds of an inch 12 inches above the ground when the trees were set, and at the completion of the growing season thereafter. The total new shoot growth was measured in inches at the same time.

Results and Discussion

Growth: At the end of the first season's growth the trees which had been cut back had made more new shoot growth than those which had merely been thinned out. Table III gives the total inches of new growth as 2658 for the 24 trees cut back, as compared with 1996 inches for the 24 trees thinned out, a gain of the former over the later of 33.1 per cent. The same season, however, the trunk diameter measurements showed that the thinned out trees had made the greater total growth—a 2.1 per cent gain for the thinned-out trees as shown in Table III.

The second year both treatments made about the same increase in trunk diameter though the total percentage increase for both seasons growth was thereby reduced to 1.1 per cent.

TABLE III—Comparison of Trunk Diameter and Shoot Growth of Apple Trees Cut Back at Planting and Thinned Out at Planting

Treatment	Number trees	At planting	Trunk diameter in 32nds of an inch						Shoot growth First season	
			One season's growth			Two season's growth				
		Total	Total	Per cent increase	Per cent gain over other treatment	Total	Per cent increase	Per cent gain over other treatment	Total inches	Per cent gain over other treatment
Thinned Out	24	473.0	572.0	20.9	2.1	848.5	79.3	1.1	1996	00.0
Cut Back	24	468.0	556.0	18.8	0.0	834.0	78.2	0.0	2658	33.1

In brief the total shoot growth was greater where the trees were cut back, but the increase in size of tree as measured by trunk diam-

eter was slightly greater where thinning out was practiced. The second season both treatments made about the same growth, but with the thinned out trees retaining their initial season's advantage in size.

Form: The Cortland tree is inclined to branch at sharp angles when young, though the later habit of the tree is open and willowy, with terminal fruiting. The result of cutting back has often resulted in giving several sharp-angled lateral branches (15 to 30 degrees) from the first 2 or 3 buds nearest the cut. On the other hand branches which were left uncut have usually thrown out several shorter growths at wider angles (45 to 60 degrees) evenly spread along the branches. The main difficulty with not cutting back has arisen where two or three branches have competed for the leader without suppression in favor of either one. The result in such cases has been bad crotches and ill-shaped trees that seem hopelessly handicapped.

In other words, well-formed trees which needed no cutting back for balancing have made the best shaped trees with fewer sharp angles, while ill-formed trees have been improved by the balancing that is incident to cutting back. The ill-formed trees which were not cut back will probably never make as good trees as though they had been balanced by cutting back.

This suggests that cutting back at planting as a matter of habit is not necessarily correct, but that after the removal of undesired branches the others should be cut back only so as to balance and shape the tree. Perhaps sharp-angled varieties like Northern Spy might better not be cut back, while wide-angled varieties like Smokehouse and Stayman Winesap might be treated differently.

SUMMARY

To sum up, then, in a test with a quickly available nitrogenous fertilizer (nitrate of soda) upon both small and large one-year Rome Beauty apple trees, average two-year Rome Beauty trees, and large one-year Baldwin trees, an application of one-half pound of fertilizer in the tree hole at planting time resulted in prompt killing excepting in the case of large one-year Baldwin trees which survived in a weakened condition. The trees receiving 8 pounds of nitrate per tree close to the tree lost their leaves in mid-summer after a series of heavy rains while the trees receiving 2 pounds, 1 pound, and one-half pound all showed burning of the leaves and decreased growth. The best trees in the test were those receiving either no fertilizer or one-half pound well back from the tree. In cases of injury the large one-year Baldwin trees were least injured and recovered most promptly, the large one-year Rome Beauty trees were next, the small one-year Rome Beauty trees next, and the two-year-old Rome Beauty trees the most quickly injured and the slowest to recover.

In a test with cutting back Cortland trees at planting versus thinning out, the cut back trees made the greater shoot growth the first season while the thinned out trees made the larger trees as shown by trunk diameter increase. The second season both treatments

made about the same increases in trunk diameter though the uncut trees retained their original advantage in size. Trees that were well-formed and not cut back made the best shaped trees, those that were well-formed and cut back were next best, those that were poorly shaped and balanced by cutting back were next, while those that were ill-shaped and not balanced by cutting back were hopelessly misshapen.

The Effect of Ringing Filler Trees in an Apple Orchard and Its Commercial Possibilities

By F. N. FAGAN, *Pennsylvania State College, State College, Pa.*

MAY it not be true that modern apple orchardists in the United States have overlooked the commercial aspects of the old practice of ringing trees to hasten fruitfulness? May it not be true that experiment station workers have accepted the true plant physiology side of ringing practice without laying enough weight upon the commercial viewpoint?

There is little need here to enter into a discussion of the physiology connected with ringing work. Our membership is familiar with the literature on this subject. There are numerous references to be found in both old and new European and American literature.

The writer has found but one reference that might be called truly commercial, Mr. L. A. Goodman of Kansas City, Missouri, states in the 1906 New York State Fruit Growers Association Report that ringing is a common practice in his orchard. Mr. Goodman reports the ringing of hundreds of trees about the first of June with little if any loss of trees, but with a marked increase in crop production the following year.

There are many orchards in eastern United States planted under the filler system where apple trees have been used as fillers. Many such orchards reach the stage when the fillers crowd and interfere with the permanent trees long before they have borne enough fruit to even pay for the cost of removing the fillers. Such a condition results into a real economic orchard problem with a heavy money loss to the orchardist.

The writer is in receipt of information from 3 commercial orchards where the filler trees should and are being removed, because they have reached the size where damage is resulting to the permanent trees. In these cases the value of the crop to date from the filler trees will not even pay for their removal let alone the other cost already charged to the fillers such as pruning, and spraying.

At the Pennsylvania State Agricultural Experiment Station, a 20-acre orchard of apples was planted in the spring of 1917. The varieties used were, Stayman Winesap, McIntosh, Rome Beauty and

Baldwin. Each block containing 540 trees planted on the corners of a 20-foot square. Each variety block was filled with its own variety.

In 1922 we could see that before many years the fillers would begin to crowd the permanents. In June of 1922 a few Baldwin trees were ringed in the customary manner, removing a quarter-inch strip of bark completely around the tree. These trees set a good crop of fruit in 1923 and were again ringed in June of that year, resulting in another set of fruit for 1924. We were testing the possibility of establishing ringing practice as a commercial method with the fillers in our own orchard.

With this preliminary work, no trees had died although it had been noted that the trees did not make as long terminal growth as the unringed trees. It was also noted that the trees invariably bloomed a day or two later than the unringed trees.

In mid-June of 1924, 18 Stayman Winesap, 18 McIntosh, 18 Rome Beauty, 119 Baldwin fillers received the ringing treatment. The 1925 crop resulting from the ringing is given in the following table:

Stayman Winesap—18 ringed trees, yielded 4 bushels per tree.

Stayman Winesap—510 unringed trees, yielded slightly less than 1 bushel per tree.

(12 Stayman Winesap trees had been removed for various causes during the past 8 years.)

McIntosh—18 ringed trees, yielded 4 bushels per tree.

McIntosh—520 unringed trees, yielded slightly less than 1 bushel per tree.

(2 trees had been removed from this block during the past 8 years.)

Rome Beauty—18 ringed trees, yielded 2 bushels per tree.

Rome Beauty—522 unringed trees, yielded less than 1 bushel per tree.

Baldwin—103 ringed trees, yielded 110 bushels.

Baldwin—417 unringed trees, yielded 10 bushels.

There was a direct loss of 4 Rome Beauty ringed trees. The death of these 4 trees undoubtedly was caused by the ringing. The wounds did not heal, however, the trees did not die until the growing season of 1925. These trees stood on a ridge where the soil is thin and is underlain with ledge rock.

In the Baldwin block 16 trees died in the summer of 1925 evidently from the direct result of ringing. These trees stood in the row next to the Rome Beauty on the ridge where thin soil is situated, underlain with ledge rock.

We do not feel that the loss of the Rome Beauty and Baldwin trees is a serious matter for it has taught us that trees so situated should not be ringed. The Rome Beauty fillers are not crowding to the same extent as the Stayman Winesap, Baldwin and McIntosh. In all probability the Rome Beauty fillers will not begin to crowd seriously until 1930. The McIntosh, Baldwin and Stayman Winesap, however, will be crowding in 1927, and the prospects are that they will not produce heavily if allowed to stand unringed. This belief

is based upon past experience with the same varieties of this age in another orchard at the Station. We expect to ring all Stayman Winesap, McIntosh, and Baldwin fillers in the early growing season of 1926. We feel that the results obtained from our ringing experience since 1922 warrants us in ringing 1125 filler trees in this orchard in 1926.

Has Ringing Any Place in Commercial Orchard Practice?

By F. S. HOWLETT, *Experiment Station, Wooster, Ohio*

THE ringing of apple trees has always been considered a dangerous practice. The uncertain results in fruit bud formation, the possibility of unsatisfactory healing of the wounded tissue, and a likelihood of injury to the tree, have caused horticultural investigators to look with extreme disapproval upon the use of the practice. However, it was felt that the possible application of ringing as a means of encouraging fruit bud formation where ordinary cultural methods had failed, had not been adequately investigated. Occasionally certain plantings are found in which varieties naturally late in coming into bearing have been planted inadvertently as fillers. Moreover, the trees may not have been set sufficiently far apart to allow for much growth before the removal of the fillers is imperative. Although they have had excellent culture, the fillers have not uncommonly continued to delay the production of a satisfactory number of fruit buds to within a few years of the time of their removal. The question has arisen, in consequence, as to how fruit bud formation can be immediately encouraged. With these facts in mind, studies have been carried on at the Ohio Station for several years to gain more knowledge of the effect of ringing upon the growth and vigor of the tree and to arrive at some conception of the possible application of the practice to filler trees.

Ringing, in the past, has been considered largely in relation to the response obtained in fruit bud formation. However, Drinkard (1915) (1917) reported in those cases in which a ring of bark one-quarter to one-half inch wide had been removed from the trunk of a tree, that the growth of the trees was good and that complete healing was obtained when the work was properly done. As far as fruit bud formation was concerned, equally good results were obtained even on moderately vigorous trees.

Van Deman (1914) reported that he had repeatedly ringed apple and pear trees without any serious injury.

Howe (1914) removed rings one inch wide from vigorous seedling apple trees for two years in succession and obtained no setback in the season's growth. However, he obtained very serious effects and no response in fruit bud formation from ringing immature Baldwin trees (3 and 4 years from planting) with rings 1 to 24 inches in width. At the present time we know that rings 1 inch in width are at least 4

times wider than necessary and that trees of Baldwin of that age and state of immaturity could hardly be expected to give satisfactory results.

Alderman and Auchter (1916) were the first to publish data to show the effects of ringing whole trees upon their subsequent growth and vigor. Unquestionably ringing the entire tree reduced the annual terminal growth, size of leaves, and total area of leaf surface.

In the work at the Ohio Station rings one-quarter inch in width have been made upon 1 or 2 of the main scaffold limbs of a tree rather than around the entire trunk. It would be expected, in consequence, that the roots of only part of the tree would be dwarfed. In all the cases in which the ring has been properly made and the wound well protected, a perfect healing resulted.

Effects of Ringing upon Growth

The data are primarily concerned with the effect of ringing 1 or more of the scaffold limbs of a tree upon the subsequent growth and vigor of the ringed portion as a result of the ringing.

The number, size, and color of the leaves as well as the length of the non-flowering terminals of the ringed limbs of a tree are compared with the corresponding indices on the unringed portion of the same tree.

Number of Leaves

There is no doubt that the foliage on the ringed limbs was somewhat sparse, which agrees with Drinkard's (1914) observations for whole trees. It is unquestionably true that this was a clear indication of a smaller number of leaves on a ringed limb than on an unringed limb of the same size. This was found to be due to the tendency of the lateral buds on the growth of the previous season to remain dormant.

Color of Leaves

The foliage on the ringed limbs of trees which were tilled or were growing in sod with adequate fertilization were dark green and vigorous. The foliage on these ringed areas in such cases differed no more in color from the foliage on the unringed limbs than was evident between the foliage on any tree which has flowered and a tree of the same variety which has not produced fruit buds. This was always true not only during the season of ringing and the subsequent year but also whether or not the ringed portion produced flowers.

Size of Leaves

One limb was ringed on May 20, 1924, on each of 35 trees of Liveland (Raspberry). Rings were also made a few days later on each of 2 trees of the Stayman Winesap. A satisfactory number of flowers was found on the ringed limbs but a heavy frost on May 24, 1925, 4 weeks after full bloom, limited the set on most trees to relatively few fruits. It was thought that a possible index of the difference in size of the leaves on the ringed and unringed portions of the trees might be obtained if the mean area of mature leaves taken from the non-

flowering terminals of the ringed limbs was compared with the area of leaves taken from the terminals of the unringed limbs of the same trees. In such a way, some indication of the effect of the practice on the ringed limbs might be obtained. The basal 4 leaves of the 1925 growth of each terminal were discarded. Collections were made of the 4 or 5 leaves from the median position of the terminals and the area of each leaf measured with a planimeter. The data for the leaves from 7 trees of Liveland and from the 2 trees of Stayman Winesap are presented in Table I.

TABLE I—Effect of Ringing upon Mean Leaf Area of Leaves from Non-flowering Terminals of Ringed Limb in Relation to Unringed Limbs, July 14, 1925

Variety	Tree number	Number of leaves measured		Mean leaf area, square inches		Difference in favor of unringed limb (+)
		Ringed limb	Unringed limb	Ringed limb	Unringed limb	
Liveland	1	100	100	6.4±.09	6.7±.09	+0.3±.13
Liveland	2	50	50	6.1±.12	5.8±.12	—0.3±.18
Liveland	3	100	95	5.2±.09	5.7±.09	+0.5±.13
Liveland	4	100	98	5.6±.09	5.6±.09	0.0
		Ringed tree	Unringed tree	Ringed tree	Unringed tree	
Liveland	5	247		4.3±.05		
Liveland	6		176		5.1±.07	+0.8±.10
Liveland	7		92		5.4±.08	+1.1±.09
		Ringed limb	Unringed limb	Ringed limb	Unringed limb	
Stayman Winesap	C1	50	69	5.2±.11	5.6±.10	+0.4±.15
Stayman Winesap	C2	75	99	5.2±.10	5.5±.08	+0.3±.12

The data indicate that there was a significant difference in the size of the leaves from the ringed and unringed portions of tree number 3 and between the leaves on ringed tree number 5 and on the unringed trees numbers 6 and 7. No significant differences were apparent between the size of the leaves on the ringed and unringed portions of the other trees irrespective of variety. As indicated by data not presented here, when flowers and fruits on a ringed limb are exceedingly heavy, there is, no doubt, a definite reduction in leaf size on the ringed portion. However, it is known that the leaves on normal unringed trees which flowered heavily and are bearing a large crop of fruit, are usually smaller than the leaves on non-bearing trees.

The objection may be raised that the measurements of leaves from the relatively small number of non-flowering terminals of ringed limbs compared to measurements from the large number of terminals on unringed limbs may not be a true index of the relative size of the leaves on the two portions of the same tree. However, it seems reasonable to assume from a study of the differences between the mean area of the leaves on the ringed limbs compared to the mean area of the leaves on the unringed portions of the same tree that ringing has at least had no serious effect which would make it unwise to use the practice with filler trees.

TABLE II—RELATION OF CURRENT LENGTH GROWTH OF NON-FLOWERING TERMINALS OF RINGED LIMB TO LENGTH OF TERMINALS OF UNRINGED LIMBS OF BALDWIN. OCTOBER, 1925

Tree number	Per cent of tree ringed	Yield of ringed limb (bushels)	Average length of non-flowering terminals (inches)				Difference in favor of unringed limb (+)	
			1924		1925			
			Ringed	Unringed	Ringed	Unringed	1924	1925
1	30	2.50	16.4±.14	18.5±.13	9.8±.12	8.8±.03	+1.9±.18	—1.0±.12
2	20	2.25	15.5±.14	16.5±.14	7.7±.27	9.0±.21	+1.0±.20	+1.3±.34
3	20	1.75	15.9±.17	16.0±.33			+0.1±.37	
4	25	0.75	18.5±.09	18.4±.13	10.0±.05	9.0±.11	—0.1±.16	—1.0±.12
5	20	0.03	19.1±.16	17.8±.11	10.3±.15	11.3±.22	—1.3±.19	+1.0±.27
6	15	0.75	17.9±.14	19.5±.16	8.6±.07	9.6±.12	+1.6±.21	+1.0±.14
7	12	0.13	18.0±.11	18.5±.10	9.3±.09	8.6±.16	+0.5±.15	—0.7±.18
8	20	3.00	18.7±.11	18.5±.12	9.6±.07	9.9±.14	—0.2±.16	+0.3±.16
9	20	1.00	17.4±.10	20.5±.15	9.2±.06	10.3±.07	+4.1±.18	+1.1±.10
10	20	1.00	23.7±.18	18.1±.15	9.9±.09	8.8±.08	—5.6±.24	—1.1±.12
11	25	1.25	16.6±.55	16.6±.42	8.8±.07	8.3±.06	0.0	—0.5±.09
12	20	0.50	20.3±.26	17.3±.06	9.3±.05	10.0±.06	—3.0±.26	+0.7±.08
13	20	0.75	20.4±.20	18.6±.11	9.6±.12	9.3±.13	—1.8±.23	—0.3±.17
14	25	0.25	20.6±.26	15.6±.24	9.6±.06	9.3±.02	—5.0±.35	—0.3±.07
Average	20.8	0.98	18.5	17.9	9.3	9.4		

TABLE III—Relation of Current Length Growth of Non-flowering Terminals of Ringed Limb to Length of Terminals of Unringed Limbs of Baldwin. October, 1925

Tree number	Average length of non-flowering terminals (inches)				Difference in favor of unringed limb (+)	
	1924		1925		1924	1925
	Ringed limb	Unringed limb	Ringed limb	Unringed limb		
1	11.7±0.97	14.6±0.67	8.3±0.24	9.0±0.19	+2.9±1.19	+0.7±0.31
2	16.2±0.25	16.3±0.33	7.5±0.30	7.9±0.30	+0.1±0.41	+0.4±0.35
3	7.9±1.19	16.0±0.35	9.4±0.52	9.6±0.25	+8.1±1.24	+0.2±0.58
4	20.6±1.38	16.5±1.27	10.6±0.08	9.0±0.27	—4.1±1.87	—1.6±0.28
5	15.0±1.03	18.3±0.69	7.6±0.56	9.2±0.55	+3.3±1.24	+1.6±0.78
6	16.4±0.47	16.4±1.09	8.0±0.72	9.5±0.28	0.0	+1.5±0.77
7	16.7±0.58	17.1±0.72	9.8±1.30	10.2±0.96	+0.4±0.92	+0.4±1.62
8	16.6±0.59	17.0±0.52	9.2±0.29	8.6±0.22	+0.4±0.79	—0.6±0.36
9	11.8±0.39	14.8±1.21	6.3±0.62	8.5±1.01	+3.0±1.31	+2.2±1.18
10	19.7±0.90	17.2±0.40	10.9±0.92	8.7±0.20	—2.5±0.98	—2.2±0.94
11	13.6±0.71	16.0±0.46	7.6±0.32	8.2±0.21	+2.4±0.85	+0.6±0.38
Average	15.1	16.4	8.7	9.0		

Terminal Length Growth

One or 2 of the main scaffold limbs of 100 ten-year-old trees of Baldwin were ringed on June 17, 1924. The trees were growing in an orchard where tillage, fertilization and cover crops were the regular cultural practices. The trees of Liveland were in the same orchard as those from which the leaf measurements presented in Table I had been taken. The Baldwin trees blossomed exceptionally well and despite an exceedingly heavy frost, bore in general, a fairly satisfactory crop of fruit on the ringed limbs. The number of measurements on these limbs was necessarily limited because of the large number of terminal flower clusters which had formed as a result of the ringing. It was felt that if serious injury had occurred as a result of the ringing it should at least, in part, be expressed in a decidedly shorter length growth of the non-flowering terminals of the ringed portion. The data obtained are presented in Tables II and III.

An examination of the data in Tables II and III show that for the terminals measured there were no significant differences between the length of those on the ringed portion of the tree and those on the unringed limbs. It is true that such measurements would probably not be a true index of the total growth of the ringed limbs as compared with the unringed portions of the same tree However, the data suggest that there was no serious dwarfing of non-flowering terminals of the ringed limbs during either the year of ringing or the year of fruiting. If serious injury had occurred to the ringed limbs as a result of the practice, it seems reasonable to assume that the length of the non-flowering terminals would have been decidedly reduced.

It is evident that when ringing has been confined to 1 or 2 of the main scaffold limbs of a tree rather than to whole trees no serious injury will result. However, even with some injury, it might be justified in view of the early removal of the trees. Unquestionably the practice is accompanied by some dwarfing effect but this is accentuated by heavy early fruiting. This dwarfing when confined to main scaffold limbs, does not seem to be appreciably greater than that commonly resulting from excessive fruiting.

Response in Fruit Bud Formation

This paper will not emphasize the satisfactory response in fruit bud formation resulting from ringing certain commercial varieties. Table IV shows, however, the average yield of the ringed limbs from 100 trees of Baldwin.

TABLE IV—Yield of Limbs Ringed June 17, 1924. Baldwin. October, 1925

Row number	Number of trees in row	Percentage of trees ringed	Yield per ringed limb (bushels)
31	14	23.6	1.20
32	17	21.2	1.12
79	13	22.1	1.51
100	56	26.1	0.57

All rows except row number 100 produced a very satisfactory crop of flowers. In the light of our present knowledge this would be ac-

counted for by the fact that the trees in this row were much smaller and less mature than the trees in the other rows. Unfortunately the set of fruit on all trees was largely decreased by an exceptionally heavy frost. The unringed portions of the trees produced no fruit buds in any case.

The response to be expected as a result of ringing will depend upon such factors as vigor and maturity of the tree. Very young and immature trees as well as small limbs on a large tree did not produce a satisfactory number of fruit buds in the case of any variety. Moreover, varieties which have a tendency to be slow to come into bearing, as Northern Spy, have so far made an unsatisfactory response in these experiments.

Ringing when confined to one or two of the main scaffold limbs of a tree did not result in a serious injury to the ringed portion. In view of this fact a limited use of ringing may be found in the encouragement of immediate formation of fruit buds on filler trees of varieties which have delayed coming into bearing beyond a reasonable length of time. It seems the better practice to confine the ringing to one or two of the main scaffold limbs followed in successive years by the ringing of the remaining limbs. The same portion of the tree in most cases will not flower the second year after ringing even if a new ring is made at the base of the limb. It is also necessary to emphasize the necessity of extreme care not only in making the ring, but also in the protection from drying and other injurious effects.

In localities where fire blight is prevalent, it may be unwise to consider ringing as a possible measure for filler trees. The shoots which tend to grow from below the ring are very succulent and if allowed to develop may become quickly infected or infection may occasionally enter through the wound itself.

In conclusion, it should be understood that ringing is not in the slightest degree to take the place of good cultural practices. The success of its use depends upon various factors which must be kept clearly in mind. At its best ringing can have only a very limited use.

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The Growth of the Fruit of the Elberta Peach From Blossom Bud to Maturity

By M. A. Blake, *Experimental Station, New Brunswick, N. J.*

As EARLY as 1918 the horticultural division of the New Jersey Agricultural Experiment Station began to take measurements of the rate of growth of the green fruits of the peach. Connors reported some of these results in the annual report of the Station for that year.

During 1924 and 1925, the author made some additional rate of growth measurements of peaches with several different objectives in view.

A peach may be considered in three dimensions—length, suture width or diameter, and thickness or cross diameter. The greatest width at any one point between the suture lines may be regarded as the suture diameter of the fruit while the cross diameter may be described as the greatest width through the center of the peach at right angles to the suture diameter.

The young fruits of our standard varieties of peaches at the "shuck fall" stage are longer than wide or thick, and the suture diameter is greater than the cross diameter. As growth continues, however, the ratio between the diameters and the length decreases until at maturity both diameters of the round fruited varieties may exceed the length. With these varieties, also, the cross diameter at maturity frequently equals and sometimes exceeds the suture diameter. These facts indicate that the fruits of the peach do not develop at the same rate in length, width and thickness during the season, and suggest the possibility of the value of dimension ratios in distinguishing varieties and as indicators of fruit development.

The 3 dimensions of typical, soft ripe fruits as picked from the trees were determined for a number of varieties of peaches at New Brunswick, N. J., in 1924. Ten rather uniform and typical specimens were measured and averaged for each variety. Considering the length of the fruit as the unit (1) the ratios of the suture and cross diameters to the length were determined. The ratios of some of the varieties measured proved to be as follows:

St. John	1—1.10—1.08	Chinese Cling	1—.95—.97
Crosby	1—1.08—1.05	Connett	1—.95—.97
Fitzgerald	1—1.06—1.06	Elberta No 1	1—.94—.87
Lola	1—1.06—1.04	Belle	1—.92—.93
Orleans	1—1.02—1.04	Iron Mountain	1—.90—.92
Eureka	1—1.02—1.02	Slappey	1—.90—.88
Carman	1—1.01—1.03	Ideal	1—.89—.88
Rochester	1—1.00—1.03	Estella	1—.98—.87

These ratios vary somewhat between different fruits upon the same tree and for the same variety in different seasons and for different localities in the same season, and should, therefore, only be regarded as approximate. They do serve to show, however, that round fruited

varieties may be readily distinguished from the more oval sorts. These differences become pronounced very early in the season and may thus be employed to distinguish between groups of varieties and some individual varieties even when the fruit is in a green state.

In 1924 at New Brunswick the dimension ratios were determined at regular intervals during the season for a considerable number of varieties. On June 16, 50 to 55 days after blooming, the ratios of several round and oval fruited varieties were as follows:

Round		*Oval*	
St. John	1—.91—.81	Belle	1—.75—.64
Eureka	1—.90—.79	Elberta	1—.75—.66
Crosby	1—.90—.78	Slappey	1—.74—.65
Fitzgerald	1—.91—.76	Iron Mountain	1—.68—.62

One can readily see from a comparison of these ratios how it is possible to distinguish between round and oval fruited varieties early in the season, and the possibilities of using the dimension ratio as an indicator in other ways.

Peaches do not grow at the same rate for the three dimensions during the season and it was decided to devote especial attention to a study of the Elberta in 1925 and to have the observations extend from blossom bud to maturity.

Selection of Twigs

The study was made of fruits upon Elberta trees in their fifth season in the orchard. In order to cover a possible range of variation in the fruits upon the trees and to study certain factors of growth, 4 series of twigs were selected.

Series 1 were twigs about 18 to 20 inches long well set with buds and located in a well-exposed position in the upper part of the top where they received plenty of sunlight. No buds or fruits were removed at any time during the season.

Series 2 were twigs similar in vigor and bud set to Series 1, but from which all the distinctly large buds were removed just before they burst into bloom.

Series 3 were twigs similar to those in Series 1 and 2 except that all the distinctly small buds were removed just before they bloomed.

Series 4 were somewhat weaker twigs located in the center of the top and well down upon the secondary branches, so that they were partly shaded and were in a less favorable position than the other series of twigs.

Each bud was tagged as soon as it showed pink and its progress closely followed throughout the season.

The number of twigs in each series was 6 and the total number of buds observed was 321, distributed as follows: Series 1—111 buds; Series 2—58 buds; Series 3—77 buds and Series 4—75 buds.

In Series 3, where the large buds only were retained, these consisted of the best developed and most advanced specimens.

In Series 2, where the small buds only were retained, the specimens consisted of distinctly smaller and more backward buds.

These were more commonly found near the base of the twig and were obviously ones which had received smaller amounts of carbohydrates for their development.

The percentages of buds blooming at different dates is recorded in Table I for Series 1 the unthinned buds upon the twigs located favorably in the upper part of the top of the tree, and for Series 4 the unthinned buds upon twigs located low down in the center of the top.

TABLE I

Date	Series 1 Per cent in bloom	Series 2 Per cent in bloom	Temperature Maximum	Temperature Minimum	Amount of sunlight
April 15	27	2	78	51	P. C.
April 16	42	10	61	35	F.
April 17	65	27	61	33	P. C.
April 18	90	42	68	39	F.
April 20	90	71	54	38	C.
April 21	98	84	57	30	F.
April 23	100	100	84	42	P. C.

Note: F—Fair; C—Cloudy; P. C.—Partly Cloudy.

The blooming of Elberta in these studies extended from April 15 to 23, with most of the more vigorous buds upon the fully exposed twigs open by April 18. The buds upon the twigs in the center of the tree were slower in expanding than Series 1. Less than 50 per cent of the buds were open on April 18 and 16 per cent did not bloom until April 21 to 23. Most of these later failed to set fruit and carry it through to maturity.

The Setting of the Fruit

There was no frost or pronounced weather injury to the peach blooms at New Brunswick while the fruit was setting and all the flowers under observation were hand pollinated to make certain that all received pollen. The flowers which opened on the 15th were exposed to cold air currents for the next two days and the "drop" of fruit was somewhat heavier than from flowers which bloomed later.

Where flowers of the peach are emasculated and no pollen reaches the stigmas, the ovary fails to swell and develop and the flower soon drops off. It is thus easy to note the flowers which do not start to develop into fruits.

The fact has been observed at the New Jersey Station since the beginning of the extensive peach experiments that blossoms of the peach sometimes drop within 10 to 14 days after blooming, even though apparently pollinated. This is frequently true of the blooms upon very young peach trees, as, for example, trees that have made only 1 or 2 season's growth in the orchard. This has been observed upon young trees even when surrounded by older trees of the same variety that bloomed full and set fruit freely. This would seem to indicate that the cause of the early drop of the blooms upon such trees in some cases is lack of nutrition of the flowers. We know that the rapidly growing twigs of very young trees are lower in carbohydrates than twigs of good vigor upon older trees. Water

sprout-like shoots in the tops of bearing trees may also be low in carbohydrates.

The flowers upon the twigs under observation in 1925 bloomed over a period from April 15 to April 23. Those buds upon the well exposed twigs which did not bloom until April 21 to 23 were the smaller and weaker ones, and this was generally true of the late blooming buds upon the twigs near the center of the tree (Series 4). All of these buds showed a high percentage of drop about May 8 or approximately 2 weeks after blooming. The percentages of drop which occurred at different periods from May 8 to June 15, 1925 from all the twigs under observation at New Brunswick, N. J., are given in Table II.

TABLE II—PERCENTAGE OF DROPPED FLOWERS AND FRUITS FROM ELBERTA TWIGS AT NEW BRUNSWICK, N. J.—MAY 8 TO JUNE 15, 1925

Period of drop	Dates of bloom in April							Per cent of total buds
	15	16	17	18	20	21	23	
April 15 to May 7	9	6	8	10	16	30	59	14.50
May 7 to May 14	2	0	6	3	4		4	3.47
May 14 to May 21	16	12	12	14	20	20	13	15.11
May 25	10	15	6	3	—	5	4	7.25
May 30 to June 2	21	15	9	13	—	—	—	12.00
June 2 to June 15	12*	18*	20*	13*	25	5	4	14.82
Totals†	73.0	68.8	64.5	59.0	66.7	60.0	86.4	66.88
Curculio June 8 to June 15	1.4	3.1	1.6	2.4				

*Per cent of drop due to curculio included.
†These percentages are figured from total "drops" April 15 to June 15 and are not sums of percentages.

The percentages of dropped fruits were noted for each series of twigs, but are not given in detail because it might unduly lengthen the paper.

The late blooming flowers which were the small buds showed a 30 to 59 per cent drop about 2 weeks after blooming, and another considerable drop about a month after blooming. By May 25, 81 per cent of all the flowers that bloomed on April 23 had dropped while only about one-third had fallen of the flowers which bloomed either on April 16, 17 or 18. It would appear from these observations that the buds which bloom very late on any one tree contribute but little toward the production of a crop.

The heaviest "drop" of flowers blooming as late as April 21–23 occurred previous to May 7 with a second heavy drop May 14–21. The so-called "June Drop" occurred from about June 2 to 15. It can be readily noted that in the case of the Elberta trees under observation in 1925 the "June Drop" was only one of several similar "drops," and that loss of flowers and fruits extended over a period from about 2 to 9 weeks after blooming.

FRUIT DROP DUE TO INSECT PESTS

The curculio is a common insect enemy of the peach in New Jersey and sometimes causes a heavy drop of the young fruits.

The insect usually appears in the orchard about the time the trees come into full bloom and starts feeding and egg-laying in the fruits as soon as the calyx or "shuck," as it is called, starts to come off. For some reason the appearance of the curculio in the Experiment Station orchards during 1924 and 1925 was greatly delayed, and fortunately, also, the infestation was very light upon the Elberta trees under observation.

In 1924, the first work of the curculio on fruits in the orchard studied was noted by Dr. Peterson of the Entomology Department, and the horticulturist on May 25. The appearance of the larvae in the fruits and any resulting drop would, therefore, not occur until some days later.

The season of 1925 was somewhat earlier than 1924, but the curculio was equally late in appearing. Each peach fruit under observation was carefully examined at frequent intervals and any feeding or egg-laying by curculio was recorded. Whenever a fruit dropped it was cut open and examined for curculio in order to definitely record the drop which might be caused by this insect. Only 5 fruits which dropped were found to contain curculio larvae or 3 per cent of all the flowers and fruits which dropped up to and including June 15. Two of these 5 fruits dropped upon June 8 and 3 upon June 15. No curculio injuries of any sort were noted upon the fruits under observation as late as June 2. The curculio was, therefore, not a factor of any importance in the "drop" of the fruit recorded in Table II. The pits of the fruits upon these trees began to harden rapidly by June 15, so there was no opportunity after this date for the curculio to make its way into the embryo and cause any further drop.

There were very few curculio feeding punctures upon any of the fruits and these did not seem to interfere with the rate of development.

Oriental Peach Moth

Larvae of the oriental peach moth enter green fruits of the peach, but no infestation of the fruits under observation had apparently occurred up to June 15.

Early Growth of the Fruits

The next stage after petal fall in the development of peach fruits most commonly noted by peach growers is the so-called "shuck spray" stage. This is quite indefinite as interpreted by different persons. Some suggest spraying when the shucks are one-half off, meaning when one-half of the fruits have entirely lost their shucks. Others mean to spray when the majority of the shucks are one-half way off each individual fruit.

In some seasons in New Jersey the curculio begins its attack upon the little fruit just as soon as it is exposed near its attachment with the receptacle as a result of the separation of the dried calyx from its base. The New Jersey Station, therefore, recommends that spraying for the curculio begin just as most of the shucks are split.

It has been found by measurements of the fruits and the calyces

that the ideal stage for the first spray for the curculio in New Jersey is when the calyx has separated from the receptacle about .10 to .15 of an inch and the suture width of Elberta fruits and of many other varieties will average about one-quarter of an inch. The dried calyx may split at 1, 2 or occasionally 3 points. When only 1 split occurs, the ideal shuck spray stage is reached when the break has expanded to about .26 to .28 of an inch; if a split at 2 points occurs then it is when the widest break has expanded to .18 to .20 of an inch. Most Elberta fruits in New Jersey will have entirely cast off the calyx when the suture diameter is .36 to .40 of an inch. Some of the fruits developing upon the weaker twigs in the center of the tree were exceptions to these figures, in that they were smaller at the ideal stage for the "shuck spray." The "shuck" or dried calyx may remain upon the tip of an occasional green fruit for many days beyond the normal period of shedding. This is especially true of some varieties, such as Iron Mountain.

Fruits from Early Blooms Reached Ideal "Shuck Spray" Stage First

The dates when the various fruits reached an ideal "shuck spray" stage are given in Table III.

TABLE III—Dates when Fruits Reached an Ideal "Shuck Spray" Stage

Date	Series 1 Exposed twigs	Series 2 Small buds	Series 3 Large buds	Series 4 Center twigs	All fruits Per cent
	Per cent	Per cent	Per cent	Per cent	Per cent
May 12	20.7	00.0	32.7	5.7	19.3
May 14	54.9	61.1	34.6	45.8	48.1
May 18	23.2	38.9	30.8	48.5	31.6
May 21	1.2	00.0	1.9	00.0	1.0
	100	100	100	100	100

On May 12, about 21 per cent of the fruits upon Series 1 twigs and nearly 33 per cent on Series 3 twigs were in ideal condition for the "shuck spray." Sixty-one per cent of these were from blooms which opened April 15 and had thus been developing for 27 days. By May 14, more than 60 per cent of the fruits upon all series of twigs except those in the center of the tree had reached the ideal "shuck spray" stage. Upon Series 4 more than 48 per cent of the fruits failed to reach this stage until May 18 or 6 days after the first fruits were ready for the spray. More than 64 per cent of these were from flowers which bloomed April 20 to 23, which means a period of development of from 25 to 28 days. What happened to these late developing fruits? Were they worth an extra delayed spray? The figures in Table II showed that 66 per cent of the flowers which bloomed April 20, 60 per cent of those which bloomed April 21 and 86 per cent of those which bloomed April 23 failed to develop into fruits which remained on the trees after June 15.

Fruits Below a Certain Suture Diameter on a Given Date Fail to Mature

It was found that all fruits that were below a certain suture diameter upon a given date failed to mature. It was further observed that the time when such fruits would drop was rather closely associated with their size at a given date. For example, upon Series 1, Twig 1, the fruits which finally matured had an average suture diameter on May 21 of 0.41 inch. Two fruits upon this twig had diameters of 0.20 and 0.22 inch. These 2 fruits dropped before May 25. Another fruit upon the same twig had a diameter of .23 inch and this dropped before May 28. Five other fruits had diameters averaging .31 inch on May 21 and these dropped previous to June 2. Two other fruits with an averaged diameter of .33 inch dropped previous to June 15. In other words, the larger the below normal fruits on the tree May 21, the longer the period before they dropped.

TABLE IV—Suture Diameters of the Largest and the Smallest Fruits and Average of All Fruits which Matured

Date	Average days from bloom	Diameter largest	Average Diameter	Diameter smallest
		Inch	Inch	Inch
May 18......	30	0.40	0.32	0.24
May 21....	33	0.47	0.40	0.34
May 25....	37	0.60	0.54	0.42
May 28......	40	0.70	0.60	0.52
June 2...	45	0.95	0.86	0.65
June 8....	52	1.28	1.12	0.98
June 15......	58	1.44	1.30	1.15
June 23....	66	1.52	1.37	1.20

One should not infer that the figures in Table IV are extreme maximum and minimum sizes for Elberta. Larger and smaller specimens could have been found in the orchard in 1925.

Only an occasional specimen as small as those listed in the last column of Table V matured. Under the conditions which prevailed at New Brunswick in 1925, all the fruits upon the trees below the smallest sizes recorded for the different dates could be considered as not being a factor in the crop.

There was some "drop" of fruits that were above the average in size, but very few dropped that were close to the maximum size. It should not be inferred from this statement, however, that the largest specimens of the green fruits never drop. They are not likely to, however, unless the trees become too succulent or too severely affected by drought, or because of some abnormal condition. If the trees make a very succulent growth in late May and June, varieties such as Slappey, Ideal and Shipper Cling may drop many of their largest fruits. Those which are below the average will also drop.

The studies seem to indicate that breeders of peaches may well avoid spending much time in pollinating the very small and late blooming buds. Peach growers will accomplish little by waiting for

the smaller fruits to reach the "shuck spray" stage before spraying. In fact, fruits below the smallest sizes given in Table V for any particular stage of development, can be eliminated from serious consideration by the grower.

Fruits Which Later Drop Fall Below the Average in Rate of Growth

In 1925 it was easily possible to predict even a considerable time in advance that certain fruits were going to drop because of their slow rate of growth. For example, one fruit upon Twig 5, Series 1, had a suture diameter of .27 inch on May 18, as compared to the average .32 inch. Its diameter measurements upon the 5 succeeding dates were .30, .36, .38, .43 and .40 inch, as compared with the normal averages of .40, .54, .60, .86 and 1.12 inches for the same respective dates.

Do Largest Buds Develop into Largest Fruits?

Another question which might be raised by such a study as this is whether the larger buds tend to develop into the larger fruits at the end of the season.

The larger buds in April have attained advantage over their fellows probably through being favored the previous season by more liberal supplies of carbohydrates. If the weather is equally favorable to all at blooming time and pollination is successful, and the same relative advantages between the buds remain the same, the larger buds would certainly tend to remain in the van.

Conditions for growth and photosynthesis often change, however, from season to season and during a season about any one twig or portion of a twig. One twig or branch may become bent down over another after blooming and the sunlight largely shut out from the under twig. Actual measurements of fruits in 1924 and 1925 showed that in such instances the growth of the fruits upon such a twig were slowed down in comparison with fruit upon twigs of equal vigor that remained well exposed to light.

Pruning, fertilization and other factors may change the light about and nutritional conditions within a twig at any time, and when this occurs the fruits upon such a twig are likely to become changed in their relative rank as to rate of growth and size in comparison with the other fruits upon the tree.

Suture Diameters, Only, Were Secured of the Fruits from May 18 to June 2

It would be a difficult and tedious matter to obtain the 3 dimensions of the fruits when they are quite small and there would be danger of injuring the fruits. Only the suture diameters of the fruits were, therefore, recorded previous to June 2, or an average of 45 days after blooming. In determining the average size and rate of growth of the fruits for the different stages of development, only the fruits which actually matured in September were considered in the averages. For example, on May 18 the average suture diameter of

the fruits is given as .32 inch. This was the average for the fruits which remained upon the trees throughout the season and matured. If all the fruits on the twigs were considered at each date previous to June 15, the figures would be of little value, since many of the fruits were making but little growth and dropping as late as June 15. The rate of growth of the 3 dimensions of the fruits at intervals throughout the season is given in Table V.

TABLE V—AVERAGE SIZE OF ELBERTA FRUITS IN THREE DIMENSIONS IN INCHES AND RATE OF GROWTH PER DAY AT DIFFERENT PERIODS AT NEW BRUNSWICK, N. J.—1925

Date	Days after bloom	Length	Suture diameter	Cross diameter	Gain per day			Dimension Ratios
					Lgth.	S-Diam.	C-Diam.	
May 18	30	—	0.32	—	—	—	—	———
May 21	33	—	0.40	—	—	.027	—	———
May 25	37	—	0.54	—	—	.035	—	———
May 28	40	—	0.60	—	—	.020	—	———
June 2	45	1.08	0.86	0.68	—	.016	—	1-.79-.62
June 8	52	1.39	1.12	0.92	.051	.043	.040	1-.79-.65
June 15	58	1.57	1.30	1.10	.025	.025	.011	1-.82-.70
June 23	66	1.63	1.37	1.18	.005	.009	.010	1-.83-.71
June 30	72	1.66	1.40	1.22	.004	.004	.005	1-.84-.73
July 6	79	1.68	1.44	1.31	.003	.006	.015	1-.84-.78
July 23	95	1.73	1.52	1.38	.002	.004	.004	1-.87-.79
July 27	99	1.77	1.56	1.42	.010	.010	.010	1-.88-.80
Aug. 5	110	1.88	1.71	1.55	.012	.016	.015	1-.89-.81
Aug. 11	115	1.99	1.82	1.64	.018	.018	.015	1-.91-.81
Aug. 19	123	2.16	2.03	1.84	.021	.026	.025	1-.93-.84
Aug. 24	128	2.20	2.09	1.91	.008	.012	.014	1-.94-.86
Aug. 27	131	2.30	2.24	2.07	.033	.050	.053	1-.96-.90
Sept. 4	139	2.47	2.39	2.24	.021	.019	.021	1-.96-.90

Range of Dates of Bloom April 15–23. Average of fruits which matured April 18. Range of Maturity August 29 to September 11. Average of fruits which matured September 4.

The length of each fruit at first was measured from the receptacle to the very apex of the fruit. By June 2 the flesh of some of the fruits was extending beyond the receptacle or the stem attachment of the fruit and the measurement was made of the extreme length of the fruit. Later the cheeks of the fruits commenced to develop downward until they extended beyond the apex in most instances leaving the latter depressed. The extreme length of the fruit was taken in all measurements.

The green fruits attained their most rapid daily rate of increase in the 3 dimensions during the period from June 2 to 8, or 45 to 52 days after blooming. This rate was not again approached during the season until August 24, when the actual ripening process was under way. The slowest rate of increase in the 3 dimensions occurred from July 6 to 23, or from the 79th to the 95th day after blooming.

The fruits grew most rapidly in length previous to June 8. During the period from June 15 to June 23, or from the 58th to 66th days while the pits were hardening, the suture and cross diameters of the fruits increased about twice as fast as the length. Again from June

30 to July 6, or from the 72d to the 79th days, the suture diameter increased twice as fast as the length and the cross diameter 5 times as fast as the length. Again from July 6 to 23, from August 11 to August 19, and from August 19 to August 27, the fruits showed more rapid increases in the suture and cross diameters than in length. It would also be of interest to study the increase in growth of the fruits in terms of volume instead of length and diameter.

The dimension ratios of the fruits at various stages should prove of considerable value in judging the stage of development of Elberta fruits in any season. In 1925, the suture diameter was a bit more than three-fourths and the cross diameter about two-thirds the length of the fruit from the 45th to the 52d day after blooming. The 2 diameters then gradually gained upon the length of the fruit as the season progressed.

The Form of Individual Fruits Varies

There is considerable variation in form between Elberta fruits upon the same tree in any one season. These variations may be grouped into several classes: 1—the long, pointed type; 2—the long, necked type; 3—a common, standard type; 4—the more rounded Hale type; 5—the truncated type, and 6—the flat-sided, clam-shell type.

Observations by the author seem to indicate that the green fruits of Elberta tend to be distinctly more pointed if the temperatures are high for the first few weeks following blooming. This has been observed in the South and with trees grown in the greenhouse. On the other hand, when the early season is cool and the trees grow slowly and an abundance of carbohydrates are available to the fruits, the suture and cross diameters are relatively greater.

Effect Upon Size and Form of the Fruit of its Location on the Tree and Twig

Fruits located at the very base of twigs from 12 to 15 inches long and well set with fruits usually had a more narrow dimension ratio and were smaller than the average. Fruits from large, prominent buds located in positions well exposed to light maintained development in advance of smaller buds less favorably situated and the form of the fruits was commonly of the well-developed, standard type. Fruits which occasionally set and mature at the very tip of upright leader twigs which continue in vigorous growth have been found to be more oval or oblong in form and more narrow in the suture diameter than average fruits.

Where two peaches developed very close to each other on the same side of a twig and one was large at the start, the other frequently developed into a more flat or long-necked type.

Two embryos develop in some of the fruits and only one in others. Where two start to develop and one later fails, the fruits have unequal halves.

Split Pit Fruits

In some seasons there are complaints that many specimens of the early varieties of peaches in particular have split pits. It has been observed at the New Jersey Station for some years that such fruits are most numerous on ringed trees or where the downward translocation of food is interfered with in such a manner that the top and twigs are high in carbohydrates. Measurements of the 3 dimensions of split pit fruits have been made of different varieties by the author, and in every case the cross diameter of the mature fruit is relatively greater in proportion to the length and suture diameter than in normal fruits. It so happened that there were several cases of split pits among the Elberta fruits studied in 1925. At maturity 1 specimen had a dimension ratio of 1—.94—.98 as compared to the ratio of 1—.96—.90 for the average normal fruits.

The dimension ratio of this fruit exceeded a normal ratio in the third dimension as early as August 5. There seems to be no doubt that this abnormal pit development is due to an excess supply of carbohydrates to the fruits that are affected.

The Season of 1925 was Dry at New Brunswick and the Growth of the Trees was not Excessive

A relatively slow but vigorous growth of peach trees tends to the production of large, firm fruits, if the set is not too heavy. These were the conditions which prevailed at New Brunswick in 1925. The flowers and fruits upon Series 1 and 4 twigs were not thinned.

At ripening time the dry weather may have slightly reduced the size of the fruits which matured, so that the last average rate of increase for the fruits given in Table V may be a bit lower than would have been the case if there had been more available soil moisture.

In a season of more rapid vegetative growth and relatively lower percentages of carbohydrates, the dimension ratio of Elberta at maturity at New Brunswick might be expected to be nearer 1—.94—.89 or 1—.94—.87.

When Elberta fruits are picked several days before they are ripe for distance shipping, their cross diameter ratio would be likely to fall below .90.

Since complete records were taken of the fruits studied at New Brunswick, some very interesting figures upon comparative rates of growth of individual fruits of different types are available, but the addition of this data would have made this paper unduly long.

Publicity Methods for Horticulture

By C. E. Durst, *Managing Editor,*
American Fruit Grower Magazine, Chicago, Ill.

I WISH to state plainly at the beginning of this paper that I am not coming before you with the object of giving recommendations

or advice regarding methods of publicity in horticulture; rather, it is my object to present the subject in the spirit of discussion.

The value of publicity is, I believe, appreciated by all of us. Publicity plays an important part in the destiny of nations. It makes and unmakes presidents and kings. It raises some people to high places in the estimation of others, while it tramples the reputation of others in the dust. It is perhaps the chief factor in directing the trend of thought of people with respect to social and economic customs, matters which affect the lives of all of us, both in a large and small way.

PUBLICITY IS SALESMANSHIP

In a general way, publicity is salesmanship. Salesmanship consists in the selling of commodities. Publicity is salesmanship because it consists in the selling of ideas. By the selling of ideas I mean the presentation of subject matter in such ways that people's lives will be influenced by it. Effective publicity is high-class salesmanship because ideas are, as a rule, difficult products to sell. The same principles must be used in the selling of ideas as in the selling of other products. The methods must be varied to suit the circumstances. But no matter what the method may be, the object is to make the ideas take hold in other people's minds. Success in publicity is measured by the number of people reached and by the extent to which they are influenced.

It has seemed to me that, as workers in colleges and experiment stations, we are sometimes inclined to feel that the conditions surrounding our activities are entirely different from those affecting other groups of people. If we will look at the matter from the standpoint of salesmanship, I think we must conclude that we are governed by the same general principles as govern most other people. Practically everybody in this world is producing and selling something. We are producing and selling ideas, the most difficult product of all to produce and to sell. We must first collect our ideas through study and investigation, and then, if we do ourselves and our institutions justice, we must sell our ideas to the public. Too many of us, I am afraid, are giving too much attention to production and not enough to selling. No one would expect a commercial concern to reach a high degree of success if it devoted all of its efforts to production and neglected the selling end. Neither can we, as horticulturists, render the largest measure of service if we fail to sell our ideas effectively, no matter how efficient we may be in producing them. Many high-class producers of ideas in the scientific world have made little progress because they have been poor sellers. Some of our best scientists have been overshadowed by less capable men who have been better publicists.

College and experiment station workers must look at this subject from three viewpoints. First, the welfare of the public, which furnishes the money for most of our institutions, must be considered. Second, the reputation and future welfare of our institutions are at stake. Third, we owe it to ourselves and our families to let the public know what we are doing.

Publicity Methods Must Fit Conditions

Because of the nature of college and station work, publicity must be of various kinds. The spoken word is one of the most effective methods, but few of us have the rare faculty of making ourselves effective in this direction. For scientific material, we must, of course, use the scientific journals. Technical bulletins and reports will always have a place. It seems to me that our methods of putting out technical and semi-technical publicity are already pretty well developed and need little comment. Popular bulletins and circulars will always be important avenues of publicity. Practical articles in farm papers must not be overlooked. Even daily papers must be considered. In the remaining remarks I am going to confine myself particularly to printed forms of popular publicity.

College and experiment station workers represent a peculiar combination. On the one hand, we want to make such contributions as we can of a technical character. On the other hand, we want to reach as many people as possible with information of a practical nature. The men who have been most successful, it seems to me, are those who have followed a balanced program with reference to technical and popular publicity. Thoughts on this subject always recall to my mind the late Dr. C. G. Hopkins of Illinois and Dean L. H. Bailey of New York. Both of these men in their active days were highly trained scientists in their respective lines, and both could command a respectable hearing before the most technical-minded audience. At the same time, both of them had the rare faculty of knowing how to reach the practical public as well Both were capable of presenting big ideas, and technical ideas too, if you please, in simple and clear language. Every horticulturist who desires to improve his publicity methods would do well, in my opinion, to study the lives, methods and writings of these two great men.

Popular Publicity is Important Factor

It seems to me that some of us under-estimate the importance of popular forms of publicity. Some of our institutions seem to have developed the idea of pure scientific research to such an extent that young men are inclined to develop a condescending attitude toward practical forms of work. At any rate, many men conduct an investigation, issue a technical or semi-technical report on the same, and quit the subject. Then they wonder why the public isn't more appreciative of their work.

Technical investigations that bring out information of practical value should be followed in most cases with popular bulletins or circulars. Many people will read these who would pay no attention whatever to a scientific publication. We should also follow such investigations with practical articles for the farm papers and daily papers. These first efforts should be followed by more articles from time to time. Many people will read such brief reports who would never read a popular bulletin or circular, much less a scientific publication. Through these various methods, the results of investiga-

tion will reach a larger audience, and they will have much more influence.

Popular Bulletins on Elementary Subjects

I think also that every one of our institutions should prepare a series of popular bulletins or circulars on elementary subjects. As we progress in our scientific studies, we tend to underestimate the value of such publicity. We must remember that thousands of boys and girls are growing up each year and that many city people are taking up horticultural pursuits. Such information is much appreciated by them and helps greatly to popularize the institution.

The form in which practical bulletins and circulars, farm paper articles and newspaper articles, goes out, makes a lot of difference in their reception. I find in looking over dozens of manuscripts that many men, like myself, have trouble in writing effective introductions. Most of us, it seems, are more or less unnatural in our opening statements. In exerting ourselves to prepare a good introduction, we often defeat our very purpose and make it a stiff unnatural affair. Many men who usually write a poor introduction write an excellent article after they get well started.

A Good Introduction is Imperative

The value of a good introduction cannot be over-emphasized. Whether a reader realizes it or not, he decides, consciously or unconsciously, in the first paragraph whether or not he is going to read the article. If the article appeals to him he will read it. If it does not, he will turn to another article with the expectation of reading the first article later. This, of course, he rarely does.

An introduction, to be effective, must be fairly short. It should lay down the viewpoint that is to be taken in the article. As a rule, it should indicate the scope of the article. It should not, as a rule, reveal the conclusion that is to be reached. It should arouse curiosity. If the article brings out a new idea or improves on the application of an old idea, the introduction should indicate the same. Such a viewpoint will arouse the reader's sense of scientific curiosity. If the article gives information of economic value, the introduction should also carry an economic appeal. Quite often an effective introduction can be planned by starting with a known idea and leading the reader off into an unknown but related field of thought. The object of the writer should be to fairly and honestly arrange the introduction so that the reader will feel he is missing something if he fails to read the article. If the subject is one which deserves treatment, there should be little difficulty in arranging an effective introduction.

Use of Involved Language

It seems to me there is a rather well defined tendency among college and station men to use involved language. Long sentences and modifying phrases are quite common. I think this is due largely to the analytical type of mind of the college and station horticulturist. He likes to exhaust every detail of thought. His fertile mind runs

out to all the related lines of thought with reference to the item under consideration. The result is that he tries to record these thoughts in his writings.

In scientific writings, it is, of course, necessary and advisable to record all the related lines of thought. Long sentences are sometimes necessary. Modifying phrases may be necessary to express the exact shade of thought desired, but even in these writings simplicity should be sought for as far as possible. There is no doubt but what far simpler forms of expression can be used than are employed by many scientific writers.

A Simple Style is Most Effective

In popular literature a fairly simple style is essential. By all means, we should avoid long involved sentences and frequent use of modifying phrases. The average reader does not like to think very hard to get his ideas. If an article is too difficult to read, or if the reader must frequently re-read paragraphs and sentences to grasp the thought, he will soon tire and turn to another article. We should not attempt, in popular publicity, to exhaust every shade of thought. It is far better to make the main line of thought stand out forcefully than to try to include every detail. In attenpting to include every detail we greatly reduce the forcefulness of the material. It is better to omit some of the detail, and in this way drive our ideas home, than to try to exhaust the subject and thus reach few readers. Of course, in deciding the style to be used, we must bear in mind the nature of the audience to be reached. Semi-technical periodicals, for instance, will permit more detail than the daily newspapers. But in all of our popular publicity, we should strive for as simple forms of expression as possible. As far as possible, sentences should contain a single thought. Few of them should contain more than two related thoughts. We should aim to plan our sentences so that they will be capable of but one interpretation. If we can accomplish this purpose and at the same time arrange our thoughts in logical sequence, we shall have little trouble in selling our ideas to any audience.

Individuality

Another matter of importance is that of individuality in writings. Every one of us possesses this trait to a greater or less extent. It is an extremely difficult thing to describe, much less to write about. It is that indescribable something which puts a personal touch in our writings and makes them stand apart from the writings of other persons. Unfortunately, the academic spirit which prevails in our scientific institutions affects all of us to a greater or less extent and many of us tend to lose our individuality in our writings as a result of it. We should attempt to retain all the individuality we possess and add to it in every way possible.

In writing articles of any considerable length, it is always well, in my opinion, to break them up into small sub-heads occasionally. Many persons will read such an article, section by section, while they would be discouraged from reading a long article set in solid type.

Furthermore, the arrangement of material under sub-heads usually results in better planning and more orderly arrangement of the material, and it tends also to insure a more balanced treatment of the different divisions of the subject.

Two Important Details.

There are many details which could be commented upon. I shall mention only two. Quite a few horticultural writers make too many attempts at emphasis. Such statements as "absolutely impossible," "completely destroyed," and others of similar nature are found too often. Such expressions, instead of adding force, which is apparently desired, detract from it. There is much more finality in the statement, "the crop was destroyed by frost," than in the statement, "the crop was completely destroyed by frost." The insertion of the word "completely" in the latter sentence suggests lines of thought to a reader that detract from the main thought intended to be conveyed.

The second point is the use of negative statements. Such phraseology as "it is not possible," and "growers should not do so and so," is found frequently. It is more effective to say, "it is impossible," or "growers should avoid doing so and so." Short snappy sentences with few, if any, modifying adjectives or adverbs, carry the greatest emphasis.

Conclusion

In conclusion I wish to emphasize again that we should give publicity its due share of consideration. All of us owe it to the public, to our institutions and to ourselves to give legitimate publicity to the results of our studies and investigations. Our value as horticulturists will depend to a large extent upon the effectiveness of our publicity. The methods to be used will vary with the conditions, with the nature of the subject, and with the audience to be reached, but in general the same principles of salesmanship which apply in the selling of any product, will bring success in the sale of horticultural ideas.

Sprays and Spraying Materials

By T. J. Talbert, *University of Missouri, Columbia, Mo.*

PERHAPS the earliest authentic record of the use of sprays for the control and prevention of injury to plants by insect pests and plant diseases is given by Pliny (9) in his Natural History. Since this was about 2000 years ago, we today are naturally greatly interested in the notions and conceptions of the people at that time as compared with our present information.

Pliny (9) in discussing "Medicaments for Trees," states: "Many people kill both ants as well as moles with Amurca (an extract from

the olive) and preserve apples from caterpillars as well as from rotting, by touching the top of the tree with the gall of a green lizard. Again, for the purpose of preventing animals from doing mischief by browsing upon the leaves, they should be sprinkled with cowdung each time after rain. Another method, again, is to pound lupines in oil, and anoint the roots with the mixture. Ashes have the same virtues as salt, only in a more modified degree; for which reason it is, that fig trees are sprinkled with them; as also with rue, to keep away worms, and to prevent the roots from rotting."

While many of the remedies and measures of controlling pests suggested by Pliny are absurd and without any foundation, yet he is to be commended for bringing together so much information stated in a simple, interesting, and effective way.

Brief History of Spraying

As early as 1779, writers mention the use of brine, lye, soap suds, vinegar, whale and fish oils, sulphur, pepper, tobacco, wood ashes, quick lime, pyrethum, and hellebore, as sprays. These substances were used separately or, in many cases, in combinations. It is needless to say that in most cases their use was not very effective. Their use, however, constituted the only means or method of combating fungous diseases and insect pests in this country and abroad before about 1860.

It is interesting to note that the substances first employed as insecticides and fungicides were not of a poisonous nature. White hellebore was the first poisonous substance employed and it was used in England as early as 1842. It was introduced in America at a later date.

Pyrethum was one of the early substances used in combating insect pests. It was introduced into France about 1850. Pyrethum consists of ground flower heads of the Pyrethum plant.

Whale and fish oils, and kerosine, were made use of at an early date, but later their uses fell into disrepute on account of the injury done when applied as sprays to the foliage and fruit of plants.

Arsenical Sprays

The development of arsenical sprays is of American origin. The occasion for their use and development was caused by the ravages of the Colorado potato beetle. It has been said that "Necessity is the mother of invention." Likewise, this was true when the so-called Colorado potato beetle began to ravage the potato fields of Colorado and Nebraska. It seemed that nothing could be brought to bear upon this insect to stop its destruction and ravages. Finally, Paris green was tried by sprinkling the substance on the foliage of the potato plants. The potato beetle was readily destroyed by this poison and the use of Paris green as an insecticide for biting and chewing insects received at once a great impetus. Its first use against this insect pest was about 1865–66.

After Paris green came London purple, white arsenic and lead arsenate. Since the introduction of these poisons many different

forms of arsenical preparations have been prepared and offered for sale to the public as insecticides. In the beginning all the arsenic preparations contained a large percentage of soluble arsenic and were soon done away with because of the injury done to the foliage and fruit of plants. Lead arsenate is the one insecticide which has the widest use at the present time. In general it is also the safest and most reliable—although it is far from perfect or what it should be as a spraying material.

This statement is confirmed by the work of Fernald and Bourne (7). Their results seem to show that the most reliable arsenicals when properly made, mixed, and applied, may cause injury resulting from the combination of temperature, humidity, and light factors.

Bordeaux Mixture

Bordeaux mixture, the oldest fungicidal spray, was discovered by accident in 1878. The honor for the discovery goes to Professor Millardette of the Department of Botany, in Bordeaux, France. The story of the discovery, although an accident, is of interest. To prevent grapes along the roadside from being stolen, the foliage and fruit of the vines near the road were treated with a combination of blue vitrol and lime water. Later in the season the grapes which had been treated appeared to possess an increased resistance to plant diseases. As a result, the problem was investigated and the discovery of Bordeaux mixture was the outcome.

Although Bordeaux is our oldest and strongest fungicide and made use of today when all other fungicides fail, yet it causes a great deal of injury and subsequent loss to producers every year. There is, therefore, a great need for a fungicide as efficient as Bordeaux in controlling fungous diseases, but at the same time possessing less caustic or burning properties.

Lime Sulphur

Lime sulphur was first used in California as a "dip" for sheep scab. About 1896 it was used as a spray for fruit trees by F. Dusey, of Fresno, California. Ten years later, in 1906, Cordley (4), of the Oregon Station, discovered that more dilute lime sulphur could be applied to the apple in foliage and fruit without material injury, and that it was also less likely to burn than Bordeaux. With this discovery, lime sulphur was soon brought into general use as a spray against fungous diseases in apple orchards and also as an insecticide in the control of San Jose Scale. It is today more generally used throughout the apple growing belt than Bordeaux or any other spray.

Self-Boiled Lime and Sulphur

As a result of experiments conducted by the U. S. Department of Agriculture in 1907 and 1908, self-boiled lime and sulphur was developed and was first made use of in the peach belt of the Ozark region of Missouri. It is a standard summer fungicide today for peaches and other stone fruits. Since its introduction it has also

been quite extensively used as a summer fungicide for apples and pears where the diseases of these fruits are not serious.

The serious objection always present in the use of self-boiled lime and sulphur is its difficulty of preparation and the fact that clogging of the nozzles is always more or less general. If applied a few weeks before harvest, it sometimes stains the fruit and reduces its market value. The strength of the different lots is also likely to vary depending upon such factors as the kind and quality of the lime and sulphur used.

Atomic Sulphur

Atomic sulphur came into quite general use in the peach growing districts shortly after the introduction of self-boiled lime and sulphur. It is a commercial preparation and was brought into use as a spray for peaches by the General Chemical Company. It is very convenient and easy to use—requiring only the addition of water to make it ready for application. The preparation, however, is expensive as compared to the home made mixture consisting of self-boiled lime and sulphur.

New Jersey Sulphur-Glue Mixture

This preparation was first recommended by the Department of Horticulture of the New Jersey Agricultural Experiment Station, in 1917. The mixture was used quite generally in the peach growing districts of New Jersey and other sections. The preparation, although more convenient and just as effective as self-boiled lime and sulphur, required a great deal of work for its preparation during the busy spraying season.

Dry-Mix Sulphur Lime

To the Department of Horticulture of the New Jersey Experiment Station, goes the credit for developing dry-mix sulphur lime. According to Farley (6) the idea was conceived in the spring of 1922, that calcium caseinate might be substituted for the glue and thus make a dry mixture of sulphur and lime which would mix without difficulty, in water. This preparation appears to be much more satisfactory as a spray for peaches and stone fruits—particularly in its preparation, as well as its use, than either self-boiled lime and sulphur or the sulphur-glue mixture.

Dry Lime Sulphur

This preparation was developed by the Sherwin-Williams Paint Company in 1916, and it is now used extensively as a spray for fungous diseases of the apple and pear. The product is also used as a dormant spray against scale insects.

The agricultural experiment stations throughout the United States differ somewhat in their reports as to the effectiveness of dry lime sulphur. A majority of those reporting, however, seem to believe that it is not as effective in the control of fungous diseases like apple scab and apple blotch where they are a real problem and serious, as sprays made from the concentrated liquid lime sulphur used at a

strength of 1 to 40. It is generally admitted by all investigators that the dry product should be used for best results at a slightly greater strength than is usually recommended by the manufacturers. The best results are usually obtained by using from 4 to 5 pounds to 50 gallons of water.

This statement is borne out for Missouri conditions by some unpublished work of Swartwout of the Missouri Agricultural Experiment Station, and Faurot of the Missouri State Fruit Experiment Station, at Mountain Grove. Dutton and Johnson (5) also state that the standard lime-sulphur solution has given in every experiment better control of apple scab than any of the dry lime sulphurs or similar materials.

According to Ballon and Lewis (2), however, liquid and dry forms of sulphur gave equally good control of apple scab, or 87.4 and 87.9 per cent respectively. They also state that a commercial brand of dry lime sulphur used at a strength of 4–50 during the season's program of treatment produced 99.7 per cent blotch-free apples. Dry lime sulphur appears less injurious to the fruit, the skin of apples being smoother and more glossy when sprayed with dry lime sulphur as compared with liquid limed sulphur even when as much of the dry was used as 5 to 50.

Spray Spreaders

Spray spreaders were developed and put upon the market in about the year 1917. Since this time they have had quite general use throughout the fruit growing sections of the country. It is still, however, a debatable question as to whether spreaders should be recommended for use in spraying such fruits as the apple. The bulk of the data so far collected seems to show that for fruits having a slick outer coat or skin, such as the grape and plum, are generally benefitted when spreaders are used in the sprays.

On the other hand, for such fruits as the apple, peach, and pear, it is doubtful whether the grower receives enough additional benefit from the use of spreaders to justify their purchase. Spreaders are made from various substances, such as soap, calcium caseinate, resin, fish oil, and lubricating oil. The use of lubricating oil emulsion as a spreader is one of the latest developments in spraying. The unpublished results of the Missouri Agricultural Experiment Station and the Missouri State Fruit Experiment Station at Mountain Grove, show that the use of a one per cent or a half per cent oil emulsion in the summer applications for various fruits gives better spreading and distribution of the insecticide and fungicide than can be procured without the oil.

Stickers

Various substances have been used as stickers or to increase the adhesiveness of the spraying materials. Chief among these, however, are resin stickers, soap, calcium caseinate, oils and greases. The use of all these materials and combinations of the same emphasize the fact that there is plenty of room for progress in this direction.

Nicotine Sulphate

Nicotine sulphate has long been used as a spray against insect pests. In fact, as a dust, it was one of the earliest products used. It was also used as a liquid spray in early times and today it is one of the safest contact sprays to be used in combination with either lime sulphur, or Bordeaux and lead arsenate. The chief objection to nicotine sulphate is its high cost and also the variability in results when used. All who have had experience with this product are of the opinion that a cheaper and more effective contact spray to use in combination with other sprays is badly needed.

Dust Sprays

The use of sulphur as a dust spray probably dates back farther than the use of any other material as a fungicide. Sulphur was used as a dust spray as early as 1846. Interest in dust sprays has passed through at least two revivals. The first wave of interest in dust applications upon apple orchards occurred from 1900 to 1908, while the second wave of interest occurred about 1912 to 1914, and even at the present time in some fruit sections, there is considerable interest in dusting.

The first movement in the interest of dust sprays for apple orchards procured its start in Missouri. Dust sprays were used in the hilly orchard land of the Ozark region where in many cases it was difficult to procure water and to operate heavy machinery over the rough land. For these reasons many growers adopted dusting practices in their orchards. By 1910, however, most of those using dust preparations had discontinued the practice and had returned to the use of liquid sprays, because they found the latter much more efficient in the control of insect pests such as the codling moth and the curculio and diseases like apple blotch and bitter rot.

From 1903 to 1908 other states, such as Delaware, Michigan, Illinois, Arkansas, Washington, and New York, became interested in dusts and dusting practices for the orchards. In some of these states —particularly the northern states, where insects and diseases are usually less serious, dusting is still an important operation, and in many instances, gives satisfactory results. This is particularly true for peach orchards in almost all localities and for vineyards on the western coast.

Within recent years there has been a marked development in dusting equipment and the materials used as dust sprays. We may look forward to worthy progress in dusts as insecticides and fungicides and also to the introduction of better equipment for application. The fungicidal value of dusting sulphur appears to be directly proportional to its fineness. The finer the material the better the distribution and adhesiveness.

Methods of Making Bordeaux Mixture

R. L. Barrett (3) a graduate student of the Missouri College of Agriculture, 1924, makes the following statement:

"Hedrick (8) says, 'Many of my correspondents state positively that no injury results from "properly made bordeaux mixture." Bulletins and horticultural press urge the necessity of using the "properly made" mixtures, though scarcely any two men make the spray in the same manner. After many years of teaching students how to make bordeaux mixture "properly," and after having talked much about the supposed virtues of bordeaux mixture made in such and such a way, I am convinced that much of such talk is worse than useless. It has made this spray a bugbear to the average farmer when in reality it is simply putting a solution of copper sulfate and the milk of lime together. *I can find no data to show that the manner of putting the ingredients together makes the slightest difference in controlling fungi or in preventing injury.* The manner of putting the ingredients together does not make a great difference in the physical composition of the mixture, and it is quite worth while to strive for a mixture of good physical composition. But the idea of failing to have a certain color, or condition of suspension, means any loss of fungicidal properties, or that the power to cause injury is thus brought about is erroneous. There is little basis for the claim so often made that "properly made bordeaux mixtures" do not injure fruit or foliage.'"

Before starting the experimental work described below letters were written to 4 experiment stations for opinions as to the proper preparation of bordeaux mixture. Following are extracts from these letters:

H. W. Anderson, Assistant Chief of Pomological Pathology, University of Illinois, writes, "The procedure in brief would be as follows: For a 200 gallon tank use a 3–6–50 formula with hydrated lime. We make up our copper sulfate solution at the rate of 1 pound of copper sulfate to 1 gallon of water usually in 50 gallon barrels. Ordinarily we use 2 barrels, filling one and allowing the copper sulfate to dissolve while the other 1 is being emptied. We also weigh out in paper bags beforehand 24 pound lots of hydrated lime. In practice I actually use only 20 pounds instead of 24 as is recommended in our circular 277.

When we are ready to spray, the tank filler is started and with the agitator going when there is a small amount of water in the tank we sift in the bag of lime. Then when the tank is about two-thirds full we pour in 12 gallons of copper sulfate solution through the screen. By the time the copper sulfate is all in, the tank is almost full. We make up the lead arsenate into a thin paste beforehand and pour this in the last thing."

C. W. Mathews, head of the Department of Horticulture, University of Kentucky, writes as follows: "We keep on hand stock solutions of both bluestone and lime. Our plan is to have 2 empty barrels available, in 1 of which we put the required amount of concentrated copper sulfate, the other, the required amount of lime solution. Fill both of these barrels approximately full of water. We use the suction pump that comes with the sprayer, and in filling the tank proceed as follows: First, pump in the barrel of copper sulfate solu-

tion, next put in 100 gallons of water, and lastly the approximate 50 gallons of lime solution.

We do not attempt to have these quantities of solution exact, only taking care, of course, to have the right amount of concentrate put in each barrel to begin with."

O. G. Anderson, of the Department of Horticulture, Purdue University, writes as follows: "Answering your inquiry concerning the manner of making bordeaux mixture, will say that we no longer recommend mixing bordeaux by the cumbersome platform mixing method. We consider first, the expense of making the platform and the problem of elevating large amounts of spray material, and finally that we get no better mixture than by the more up to date methods. This method is discussed on page 7 in a marked paragraph of the enclosed bulletin."

The Extension Service of Purdue University (11) recommends the following method of making bordeaux mixture: "It will require 4 gallons of stock copper sulfate solution and 6 pounds of hydrated lime for each 50 gallons of bordeaux mixture to be made. Fill the spray tank with water and start the agitator, then make a thin paste of hydrated lime and pour it into the tank. After the lime is thoroughly churned into a milky solution add the copper sulfate, continuing the agitation. The result is bordeaux mixture ready for use. The mixture deteriorates rapidly and ought not to be allowed to stand over night."

J. R. Cooper, head of the Department of Horticulture, University of Arkansas, states: "We are mixing bordeaux for our regular spraying in the way you mention: that is, we put in our copper sulfate, fill the tank half full or more, and slowly add the lime while the agitator is running and while the tank is still filling, after which we add the arsenate of lead."

"We have tested this out very thoroughly under field conditions with other methods of mixing, and while bordeaux mixture made according to this formula settles in the laboratory a trifle faster than when made according to some of the other methods, we have gotten just as good results in the field. In fact, I have never been able to tell the difference."

"The expressions of these 4 authorities are in accord in one matter, i.e., that the old platform method is not necessary for the successful making of bordeaux mixture. Two advocate strong copper to weak lime, one dilute lime to dilute copper and one strong lime to weak copper. Each station is satisfied that its particular method is entirely satisfactory and as good as the mixture made by the cumbersome platform principle."

The work of the Missouri Station in 1924 and 1925 shows that the manner of putting the ingredients together made no material difference in controlling fungi or in preventing injury to foliage or fruit. It is also interesting to note that when the mixture was allowed to stand for 40 hours before using, no greater injury was produced with the deteriorated Bordeaux than that made and used at once.

Lubricating Oil Emulsion

The introduction and use of lubricating oil emulsion as a spray for deciduous fruit trees again emphasizes the fact that when the spray problem at hand seems to require a better spray, it is developed or introduced as a rule without great delay. Such was true of lubricating oil emulsion.

The apple growers of Northwestern Arkansas for the years from about 1917 to 1920 experienced great difficulty in controlling San Jose scale. Since many of them strongly maintained that lime-sulphur had been thoroughly tried and found wanting, they began to cast around for help and for a spray more efficient against the scale.

Finally an appeal was made to the United States Department of Agriculture. In response to this, Akerman was sent to Northwestern Arkansas to investigate the problem and offer assistance if possible. Upon the strength of the work of Yothers (13) and other workers of the Department engaged in spraying citrus trees with lubricating oil emulsion in Florida, it was believed that the same spray would control San Jose scale on deciduous fruit trees without danger of injury. Accordingly, experiments were started and as early as 1920 many apple producers in Northwestern Arkansas sprayed their orchards with lubricating oil emulsion (Government formula).

In general it was believed that the sprays were more successful than lime-sulphur. The oil emulsion was adopted in 1921, 1922 and 1923 by a large percentage of the growers of not only Arkansas, but South Missouri, Tennessee, and Southern Illinois.

Missouri Cold Mix Oil Emulsions

The investigations of the Missouri Agricultural Experiment Station Department of Horticulture, developed the fact that oil emulsions could be made without soap or heat. To do this, it was only necessary to use the materials which had previously been employed as stabilizers. These substances acted as emulsifiers without heat just as the soap had with heat.

The cold emulsions can be prepared more cheaply and easily than the oil-soap emulsions. They also have another advantage in that they can be used with hard water, lime-sulphur, and in barrels or tanks contaminated with lime or lime water without breaking down. They are compatible with all combination sprays.

Field tests and investigations made by the Station have shown the cold emulsions to be just as effective in the control of San Jose scale as the oil-soap emulsion. Observations and experiments indicate that there is no more likelihood of injury in the use of cold emulsion than with oil-soap emulsions, although the latter is generally somewhat more stable.

Position of Commercial Concerns

To commercial concerns goes the credit for leadership in introducing sprays and spraying materials. Agricultural experiment stations have generally followed, testing one spray material after another as

fast as they have been placed upon the markets. Whether this is as it should be or not, is a question upon which we will not all agree.

On behalf of commercial concerns, it must be said that they are often able to employ the best of talent and make use of the most modern materials and equipment. Consequently, they have rendered substantial aid and assistance to spraying investigational work. Perhaps the chief criticism of their work is that the methods and practices employed, and the results obtained are usually withheld from the public, other companies, and agricultural experiment stations. In other words, the information obtained is usually considered a "trade secret." As a result competitors and agricultural experiment stations are deprived of opportunities to make further advancement from their investigations and research work.

Since agricultural experiment stations are endeavoring to serve by seeking the truth without gain or profit, this fact may be advanced as a reason for their leadership in spraying investigations instead of commercial concerns. Moreover, the public generally and all other interests, are given the advantage of their observations and findings. As a result, therefore, greater progress is likely through experiment station work, providing the stations take advantage of the opportunities.

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The Cold Storage Behavior of Cherries

By E. L. OVERHOLSER, *University of California, Berkley, Calif.*

THE cold storage of cherries has not been extensively studied. The report herewith presents certain data obtained as a result of from 1 to 3 seasons studies, conducted at the University of California at Berkeley.

NATURE OF EXPERIMENTS AND METHODS OF PROCEDURE

Studies made of the following points are reported: (1) The effect of storage temperature upon the keeping period; (2) the effect of maturity when harvested upon the keeping quality; (3) the effect of delay in storage upon keeping quality; and (4) the average keeping period in days of cherry varieties at room temperature (65° to 75°F.) and in cold storage (33°F.).

HANDLING THE FRUIT

The cherries were picked, carefully placed in 5 pound grape baskets and in most cases brought into the laboratory, preliminary observations made and the fruit placed under the initial conditions of the experiment within 6 hours after harvesting (with the exception of delayed storage).

Two to 6 five-pound baskets of the cherry varieties were picked at 3 different stages of maturity.—(1) the first picking was made 3 to 5 days previous to the main commercial picking of each variety; (2) the second picking was made approximately on the day of the main commercial picking and (3) the third picking was made 3 to 5 days after the main commercial picking.

After the fruit was brought to the laboratories the degree of ripeness, the color, and the condition of the fruit were noted. A portion of each picking was then placed in the cold storage temperatures and a portion was permitted to ripen at room temperature (65° to 75°F.). This latter was done to determine the length of time the cherries kept with cold storage.

At intervals of 2 or 3 days portions of each picking in each cold storage temperature were removed from cold storage to room temperature of 65° to 75°F to ripen. While ripening the cherries were kept on cardboard plates in dark, ventilated lockers.

Each lot of fruit after removal to room temperature was observed daily. At each observation the following points were noted: (a) general condition; (b) degree of ripeness; (c) juiciness and texture; (d) flavor and quality, and (e) amount of wilting and rotting.

With the cherries in cold storage, an optimum period and a maximum period, together with the average number of days the fruit remained marketable when removed from storage at each of these periods, was determined.

The optimum storage period referred to the average number of days the fruit could be stored and upon removal possess quality and marketability nearly as satisfactory as the non-stored fruit.

The maximum storage period referred to the time beyond which it was unsafe to keep the fruit in storage, although it was still in good condition, because of likelihood of loss of quality, softening of texture, susceptibility to rot organisms, tendency to wilting, and rapidity of breakdown after removal.

The marketable period referred to the days the fruit retained its quality, flavor, color, and general condition satisfactorily to be readily saleable in the retail market. This was determined for the cherries that were not stored and also for the cherries after removal from cold storage at both the optimum and maximum storage periods.

The Effect of Storage Temperature Upon the Keeping Period of Cherries

Lots from each of 3 pickings of 51 varieties were stored at 32°, 36° and 45°F. in cold storage, and at 65° to 75°F. or room temperature. The storage periods of all the lots at any one temperature were averaged to give the average behavior. The data are presented in Table I.

TABLE I—The Average Storage Periods of Cherries as Affected by Temperature (Average of 3 Pickings of 51 Varieties, 1921, 1922, and 1923)

Temperature	Optimum storage period (days)	Days marketable after removing	Maximum storage period (days)	Days marketable after removing	Days to failure in storage
32°F.	14	5	22	5	37
36°F.	12	5	19	4	32
45°F.	8	5	14	4	28
65°F.-75°F.	4	4	7	1	11

The lower the temperature down to 32°F. the better the keeping quality of the fruit. In general the cherries kept about 3 times longer at 32°F. than at room temperatures of 65° to 75°F.

The Effect of Ripeness When Harvested upon the Keeping Quality

With all quickly perishable fruits there has been a belief that the more green or immature the fruit was harvested the better the fruit would keep. As a result the tendency has been occasionally to sacrifice eating quality and appearance in order to supposedly obtain superior shipping quality.

For this experiment 24 varieties of cherries picked at the 3 different stages of maturity were employed. The data are shown in Table II.

Within the limits of the degrees of maturity studied there was no marked difference in the keeping qualities of the 3 stages of maturity although there was in general a day or 2 of difference in the favor of the keeping quality of the first as compared to the last picking. The quality, flavor and appearance of the second and third pickings were superior to the fruit of the first picking.

Observation upon a few varieties showed, however, that immature cherries tended to wilt badly, while the fruit which was well advanced in maturity when harvested quickly became soft and rotted after picking.

TABLE II—THE EFFECT OF MATURITY UPON KEEPING QUALITY OF CHERRIES IN STORAGE. (AVERAGE BEHAVIOR OF 24 VARIETIES.)

Picking	Average harvesting date	Aveage number days kept to different storage periods						
		Marketing 65°–75°	45°F.			32°F.		
			Optimum	Maximum	Failure	Optimum	Maximum	Failure
First	May 25	8	12	17	28	16	24	35
Second	May 29	7	12	17	27	16	24	36
Third	June 2	6	11	16	25	14	21	35

THE EFFECT OF DELAY IN STORAGE UPON THE KEEPING QUALITY OF CHERRIES

Nine, five-pound baskets of Black Tartarian, Napoleon and Rockport were harvested at approximately optimum maturity for picking. One basket of each variety was placed at once in each of the 3 temperatures 32°F., 36°F. and 45°F.; one basket each was stored after being kept at room temperature for 30 hours, and the third lot of one basket each was stored after 52 hours delay. The data obtained are presented in Table III.

The data indicate an appreciable shortening of the average storage period at each of the 3 temperatures as a result of delay in storing. The longer delay reduced the storage period more greatly than the 30 hours delay.

THE AVERAGE KEEPING PERIOD (IN DAYS) OF CHERRY VARIETIES AT ROOM TEMPERATURE (65° to 75°F.) AND IN COLD STORAGE

An attempt was made to determine approximately the relative keeping quality of the different varieties at room temperature and in cold storage. The observations are given in Table IV.

The data in Table IV indicate that of the cherries studied, those that generally retain their marketable appearance and eating quality most satisfactorily in cold storage are the varieties as follows: Republican, Black Tartarian, Napoleon, Windsor, Pontiac, Coe, Eagle, Bing and Lambert.

TABLE III—THE EFFECT OF DELAY IN STORAGE UPON THE KEEPING QUALITY OF CHERRIES (1922)*

Time of storage	Average storage periods in days								
	At 32°F.			At 36°F.			At 45°F.		
	Optimum	Maximum	Fail.	Optimum	Maximum	Fail.	Optimum	Maximum	Fail.
Immediately	15	26	48	12	24	43	8	17	34
30 hours delay	10	22	43	8	18	41	6	14	29
52 hours delay	8	19	39	6	15	37	5	12	25

*Average of the behavior of Black Tartarian, Napoleon, and Rockport.

Those varieties which were unsatisfactory for storage at 32°F. were the Early Richmond, Elton, Wood, Royal Duke, English Morello and Baumann May.

TABLE IV—THE KEEPING PERIOD OF CHERRY VARIETIES AT ROOM TEMPERATURE (65°–75 F.) AND IN COLD STORAGE (32°F.). (AVERAGE OF 3 PICKINGS, EACH SEASON.)

Variety	Days marketable 65°-75° (without cold stor.)	Cold storage period in days at 32°F.					
		Optimum storage	Days marketable from optimum	Marketable storage	Days marketable from storage	Days to failure	Number of years observed
Republican	10	27	6	40	5	50	3
Black Tartarian	10	24	7	38	6	50	3
Napoleon	11	23	7	33	6	45	3
Windsor	9	22	6	33	6	43	3
Pontiac	9	21	6	31	5	43	3
Coe	10	21	7	30	5	43	3
Eagle	8	20	5	28	4	42	3
Bing	8	19	6	28	5	41	3
Lambert	8	17	6	28	6	40	2
Knight	7	17	5	27	4	38	3
Burbank	6	17	5	25	4	35	2
Centennial	7	16	5	25	4	37	2
Rockport	8	16	5	23	4	38	2
Chapman	7	15	5	23	4	36	3
Calif. Advance	7	15	4	23	4	34	3
Abundance	6	14	5	23	5	32	2
Lg. Montmorency	9	14	6	22	5	35	2
Early Richmond	7	13	5	19	4	27	2
Elton	6	12	5	19	4	31	2
Wood	6	11	5	17	4	32	2
Royal Duke	7	10	5	17	4	32	3
English Morello	7	10	5	17	4	32	2
Baumann May	7	7	4	12	2	22	3

The data represent the behavior under favorable conditions, in that the fruit was picked fairly close to the optimum condition of ripeness, carefully handled, and placed with minimum delay into cold storage. The data should not be taken as indicating sharp differences that would invariably be found under all conditions.

The data, however, in a general way do indicate relative differences in keeping quality of certain of the more commonly grown cherries.

The sour cherries did not keep so satisfactorily as did the sweet cherries.

SUMMARY

1. The average effect of the storage temperature upon the keeping of cherries as indicated by the response of 51 varieties was for the optimum period,—4 days at room temperatures of 65° to 75°F.; 8 days at 45°F.; 12 days at 36°F., and 14 days at 32°F.

2. Similar effects of the storage temperature upon the maximum and failure periods of cherries were also observed.

3. Cherries harvested 5 and 10 days later than the first commercial picking kept almost as satisfactorily at room temperature, 45° and 32°F., although there was a slight tendency for the first picking of most varieties of the 24 employed to keep somewhat longer.

4. Delays of 30 and 52 hours in placing at low temperatures of 32°F., 36°F., and 45°F., markedly shortened the keeping period. The longer delay more greatly decreased the storage period.

5. The better keeping varieties of sweet cherries were retained at 32°F. in good marketable condition for about 3 weeks and upon removal from storage remained marketable for from 6 to 7 days longer.

6. The poor keeping varieties of cherries could be similarly retained in storage for only 7 to 10 days and remained marketable after removal for only 4 or 5 days.

7. In general the sour cherries did not keep so satisfactorily in cold storage as did the better keeping varieties of sweet cherries. The keeping qualities at room temperatures, however, were not so noticeably different.

ACKNOWLEDGMENTS

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Soft-Scald and Breakdown of Apples as Affected by Storage Temperature

By H. H. PLAGGE, *Iowa State College, Ames, Iowa.*

A CONTROL for apple-scald has been successfully worked out by Brooks, Cooley and Fisher (1) of the United States Department of Agriculture. The use of oiled wraps in the packing of boxed apples has now become a general practice in the western fruit districts. It has also been shown by Brooks and Cooley (2) that oiled straw, shredded oiled paper and layers of oiled wrappers have given practically as good control of scald as wrapping in oiled wrappers.

However, the manner of controlling certain types of breakdown and soft scald on apples in storage has not yet been fully considered. The occurrence of these 2 storage diseases under both experimental and commercial storage conditions has been observed by the Pomology Section of the Iowa Agricultural Experiment Station for a number of years. In certain instances, soft scald and internal breakdown of apples have been noted to be of more consequence than

*Deceased

either apple scald or Jonathan spot. For a number of seasons, it has been observed that Grimes begins to "go down" toward the latter part of the year when stored at 32°F., while other fruit of the same variety is still sound under common storage conditions where the temperature averages considerably higher throughout the season. This variety often becomes seriously affected with internal breakdown when it should still be in prime condition. The same is true for Jonathan with respect to soft scald.

Results of previous experiments (7) carried out at Ames show that internal breakdown on Grimes is not necessarily conditioned by late maturity or by various degrees of ripeness due to differences in time of picking or delay in storing. There is some reason to conclude that breakdown can better be controlled by regulation of storage conditions rather than by altering the conditions during the harvest period. However, with Jonathan, delayed storage has materially affected the development of soft scald; a long delay having entirely prevented it. But delayed storage has increased the development of Jonathan spot on this variety.

The fact that Jonathan and Grimes often keep better under common storage or air cooled storage conditions than under cold storage, with respect to soft scald and internal breakdown, has suggested the study of storage temperature, as it affects these 2 disorders.

Outline of Experiments

In these experiments the fruit was given different treatments, such as, varying the time of picking, time of storing, aerating during delayed storage and during the storage period, as well as varying the temperature conditions. Notes were taken on the occurrence of apple scald and Jonathan spot. However, only soft scald and internal breakdown will be considered in this paper, and these as they are affected by storage temperature. These 2 storage disorders are similar in that they occur under the same temperature conditions. However, the 2 are not usually prevalent on the same variety. Kidd and West (4) in a recent publication, place internal breakdown and soft scald in the same category. They conclude that the main causal condition of the two are the same, namely, either too low a storage temperature or too long a period on the tree. The author of the present paper considers these as 2 distinct diseases because of certain dissimilarities of the 2, yet to be considered.

In the present experiment under consideration Grimes and Jonathan were used. The work was carried out in the cold storage rooms of the Pomology Section and in an air cooled storage house in the vicinity of Ames. The fruit was grown and packed at the experimental orchard at Council Bluffs and was shipped by express to Ames. It was received for storage the day after it was picked when immediate storage was the plan. When given delayed storage treatment, the fruit went into storage at weekly intervals varying from 1 to 3 weeks. The storage temperatures employed were 30°, 32°, 34°, 36° and 40°F. Some fruit was placed in an air cooled storage house

where the minima and maxima temperature ranges for the months of storage were as follows:

October	44°—60°F.
November	32°—54°F.
December	32°—39°F.
January	29°—34°F.
February	30°—34°F.
March	34°—42°F.

The relative humidity of the cold storage rooms was maintained between 80 and 85 per cent, while that of the air cooled storage house ranged between 60 and 98 per cent. The humidity of the latter was at approximately 65 per cent most of the storage period. The fruit was examined in January.

Breakdown on Grimes

The condition of Grimes in January with respect to breakdown at various cold storage temperatures and under air cooled storage is given in the following table:

TABLE I—Effect of Storage Temperature and Delayed Storage on Internal Breakdown on Grimes; Condition in January after Four Days Removal from Storage. Apples Picked Oct. 6, 1924

Lot number	Storage Temperature	Number of days delay before storing	Percentage of internal breakdown
1	30°F.	1	24.4
2	30°F.	7	58.3
3	30°F.	14	54.0
4	32°F.	1	11.2
5	32°F.	7	44.6
6	32°F.	14	0.0
7	34°F.	1	0.0
8	34°F.	7	0.0
9	34°F.	14	0.0
10	36°F.	1	0.0
11	36°F.	7	0.0
12	36°F.	14	0.0
13	40°F.	1	0.0
14	40°F.	7	0.0
15	40°F.	14	0.0
Air Cooled Storage, Apples Picked September 29			
16	29°-60°F.*	1	0.0
17	29°-60°F.*	7	0.0
18	29°-60°F.*	14	0.0

*The minima and maxima temperatures for the various months in air cooled storage, were as follows: October, 44°-60°F.; November, 32°-54°F.; December, 32°-39°F.; January, 29°-34°F.

The above table gives the percentage of breakdown occurring in each storage lot of Grimes. At temperatures of 34°F. or higher, breakdown has not appeared while at temperatures 30°F. and 32°F., it was usually abundant. This is significant in that 30° and 32°F. approximate the usual commercial cold storage temperatures for Grimes. No breakdown occurred under air cooled storage at this date. The experiment with cold stored fruit terminated in Janu-

ary, but a subsequent examination of the air cooled stored fruit, 2 months later, did not reveal any breakdown. The time of storing did not consistently influence the amount of breakdown at 30°F., but at 32°F., a 2 weeks delay entirely prevented it. Breakdown in this consideration is assumed as breakdown in its broadest sense; that is a slight tendancy toward mealiness was not considered as breakdown.

It may be well to point out the recent work of Haynes (3) who determined the acidity of apples at different intervals during the storage period for fruit held at 33.8°F. (1°C.), and 59°F. (15°C.). This investigation indicates that evidence was obtained which designates that high acidity and a slow rate of loss of acid are conditions favoring internal breakdown, and that it would be decreased if apples were not exposed to low temperatures until their acid content was reduced. The possibility that the slow rate of loss of acid in apples held at 32°F. or lower, favors breakdown, is presented. Kidd and West (4) in working with Bramley seedling, Blenheim Orange, and King Pippin in England, show similar results in that a storage temperature lower than 33.8°F., (1°C.), is conducive to internal breakdown.

Soft Scald on Jonathan

Jonathan stored under the same temperature conditions as noted in the above experiment with Grimes, showed responses as indicated in the following table with respect to soft scald.

TABLE II—Effect of Storage Temperature and Delayed Storage on Soft Scald of Jonathan, Apples Picked October 7

Lot number	Storage Temperature F.	Number of days delay before storing	Percentage of soft scald
1	30	1	42.3
2	30	7	18.9
3	30	14	10.3
4	30	21	0.0
5	32	1	6.9
6	32	7	0.6
7	32	14	0.6
8	32	21	0.0
9	34	1	0.0
10	34	7	0.0
11	34	14	0.0
12	34	21	0.0
13	36	1	0.0
14	36	7	0.0
15	36	14	0.0
16	36	21	0.0
17	40	1	0.0
18	40	7	0.0
19	40	14	0.0
20	40	21	0.0

At temperatures of 34°, 36° and 40°F., soft scald did not appear. The disease was very abundant at 30°F., and rather severe at 32°F.,

on the fruit which was stored immediately after picking. Delayed storage for 3 weeks prevented the disease at temperatures 30°F., and 32°F. Less soft scald was present on the fruit delayed for either 1 week or 2 weeks, than on the fruit stored immediately at 30°F. The amount of soft scald present tends to be proportional to the length of delay given, when the storage temperature is 30°F.

Comparison of Development of Soft Scald Under Common Storage and Cold Storage Conditions

A comparison of the amount of soft scald developing at 32°F. in cold storage, and the amount developing in an air cooled storage house are given in Table III.

These data indicate strongly that soft scald on Jonathan is very liable to occur at 32°F. In this experiment the temperature of the common storage room did not reach 32°F. until late in November. In October the temperature range was between 44° and 60°F. These higher temperatures would necessarily permit the ripening processes to take place at a much more rapid rate than at the cold storage temperature 32°F. The results herein reported agree with the work of Magness and Burroughs (5) who noted that practically no soft scald developed at a cellar storage temperature of 35°F., but found it very severe at 32°F. Marble (6) states that Jonathan and Rome Beauty should be stored at 32°F. and above in order to prevent soft scald.

In Table III it will be noted that delayed storage such as may occur at the orchard or in transit, plays an important part in checking the development of soft scald. The data show that the time of picking has only a minor influence on soft scald development and that the time of storing plays a more important role. Earlier experiments on the maturity of Jonathan reported by the Iowa Agricultural Experiment Station (7) corroborate these results.

TABLE III—Comparison of the Amount of Soft Scald Occurring Under Cold Storage and Air Cooled Storage Conditions

Lot number	Date of picking	Number of days delay before storing	Percentage of soft scald in January	
			Cold storage 32°F.	Air cooled storage*
1	September 30	1	10.2	0
2	September 30	7	8.6	0
3	September 30	14	3.0	0
4	September 30	21	0.0	0
5	October 7	1	18.3	0
6	October 7	7	3.4	0
7	October 7	14	0.3	0
8	October 7	21	0.0	0
9	October 11	1	4.8	0
10	October 11	7	2.9	0
11	October 11	14	1.7	0
12	October 11	21	0.0	0

*The minima and maxima temperatures for the various months of the air cooled storage house were as follows: October 44°–60°F., November 32°–54°F., December 32°–39°F., January 29°–34°F.

Discussion

The fact that Grimes and Jonathan and other varieties have been known to keep for a longer period under common storage temperatures than under cold storage temperatures as low as 32°F. or lower, has led to the study of storage temperature and its effect on certain storage diseases.

Internal breakdown was found to be very severe at temperatures of 30° and 32°F. on Grimes, but was entirely absent at 34°, 36° and 40°F. This was noted as late as January 20. Grimes held under air cooled storage conditions where the temperature range was much higher during the first 2 months of storage, showed no such type of breakdown as noted on the cold storage fruit in January nor as late as March 20. Since breakdown occurred on Grimes at the lower cold storage temperatures in January, but not on fruit under air cooled storage at higher temperatures as late as March, it is suggested that there may be 2 types of breakdown, 1 type occurring early in the storage season which is caused by too low a storage temperature, the other type occurring late in the season and being the result of physiological deterioration.

The affected tissues in the type of breakdown caused by too low a storage temperature are noted to have a soggy and watery appearance. The tissues are usually not lacking in juiciness, are free from mealiness and are light brown in color. The texture of the affected tissues resembles that of certain varieties of apples after baking, especially those varieties whose tissues retain a certain amount of firmness. A very distinctive alcoholic taste is noticeable in affected apples, for both discolored and normal tissue. This taste is sometimes noticeable before discoloration of tissue takes place.

In contrast to the soggy type of breakdown, the tissues of the mealy type of breakdown present a mealy dry and often a crumbling appearance. These tissues lack in juiciness and in the earlier stages no discoloration is discernible. This is the most common type of breakdown and is generally recognized as the result of progression in ripening processes. It is often accompanied with bursting of the skin under certain conditions of storage. Mealy breakdown commonly appears prematurely when the storage temperature has been too high or when the fruit has been stored in an overripe condition. It is frequently present when certain varieties have been held beyond the proper limit of the period of storage. Mealy breakdown is mostly associated with long storing while the soggy type of breakdown occurs rather early in the storage period. Large specimens of fruit appear to be more susceptible to mealiness than smaller specimens. This is in contrast again to the soggy type of breakdown for in the latter case size of fruit appears not to influence the amount of breakdown occurring.

There may be various degrees of either type of breakdown. A slight trace of mealiness would of course be recognized as the be-

ginning of mealy breakdown. Breakdown accompanying water core and bitter pit is of the mealy type.

The soggy type of breakdown as herein noted and described is likely a factor which largely determines the life of Grimes in storage. That this type of breakdown occurs somewhat early in the storage period, that it can be eliminated by storing at a slightly higher temperature than those commonly used, and that Grimes held at a slightly higher temperature kept in a more satisfactory condition, are points to be considered in the storage of this variety. Certainly the hazard of storing this variety will be reduced if it is possible to eliminate this trouble which is now commonly recognized and classified with mealy breakdown, or as a breakdown due to progression in ripening processes. It may be further suggested that the storage life of Grimes and possibly other varieties may be considerably increased by the elimination of this type of breakdown described herein as soggy breakdown.

The treatment at the orchard such as varying the time of picking and the time of storing, has not affected the amount of breakdown developing on Grimes as much as slight temperature variations thruout the storage period.

Jonathan has soft scalded severely at temperatures of 30° and 32°F., but not at 34°, 36° and 40°F. It also has not become affected with soft scald when stored under air cooled storage. The evidence obtained indicates that this disease is caused by low temperature conditions. The practicability of controlling soft scald on Jonathan by increasing the storage temperature by a slight margin over the temperatures commonly used in commercial practice is suggested. The situation with soft scald on Jonathan is similar to that of the soggy type of breakdown on Grimes. It is important to consider that Jonathan spot is usually more severe at temperatures higher than 32°F., but under the conditions of the experiments conducted, soft scald has been of much greater commercial significance.

The role that delayed storage plays with soft scald and Jonathan spot should be considered. Two weeks delay or more at the orchard at ordinary temperatures has usually reduced soft scald to a negligible quantity when stored at 32°F. but under this condition, Jonathan became very susceptible to Jonathan spot. The fact that soft scald has been less frequently reported on Jonathan from the orchards of the western states may be due to the amount of delay that this fruit receives before it is placed in cold storage. In the smaller orchards of Iowa, the fruit is sometimes stored a few days after it is picked. This may account for the prevalence of soft scald on Iowa grown Jonathan such has been reported for a number of seasons.

Summary

1. A study of the storing of Grimes and Jonathan at various temperatures has shown that Grimes is very susceptible to internal breakdown and Jonathan to soft scald at storage temperatures of 30° and

32°F. Internal breakdown did not occur on Grimes nor soft scald on Jonathan at temperatures of 34°, 36° and 40°F., or at temperatures of an air cooled storage house.

2. More breakdown occurred on Grimes and more soft scald on Jonathan at a storage temperature of 30°F. than at 32°F.

3. It is suggested that there may be 2 types of breakdown, the one the result of too low a temperature, the other the more common type the result of natural deterioration. The former is described as watery or soggy in texture, shows brown discoloration of the flesh and often brown discoloration of the skin. The latter type is the dry, crumbling, mealy type which is often accompanied by bursting of the skin, but not necessarily with discoloration of the flesh. The soggy type of breakdown occurs rather early in the storage period. The mealy type being the result of ripening, usually occurs at a time near the end of the storage period.

4. The treatment at the orchard such as varying the time of picking and the time of storing, has not affected the amount of breakdown developing on Grimes as much as slight differences in the storage temperature throughout the storage season.

5. Delayed storage at ordinary orchard temperatures has consistently reduced the development of soft scald on Jonathan. Since delayed stored Jonathan are much more susceptible to Jonathan spot, a consideration of the storage temperature throughout the storage season offers a better method for controlling the 2 diseases than does delayed storage.

6. The possibility of controlling soft scald and a type of breakdown of certain varieties of apples by increasing the storage temperatures by a slight margin over the temperatures commonly used in commercial practice is suggested.

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Color Pigment in Relation to the Development of Jonathan-Spot

By W. T. PENTZER, *Iowa State College, Ames, Iowa*

RECORDS compiled by the United States Bureau of Markets (9) show that 13.1 per cent of the average yearly boxed apple crop developed Jonathan spot and that 16.0 per cent of the fruit that is barrelled became spotted. Fruit affected with Jonathan spot is discounted upon the market, and results in a direct loss to growers and dealers. In addition, such fruit affects the confidence of the buying public in an unfavorable manner.

RELATIONSHIP OF DISEASE AND COLOR

Jonathan spot can be attributed to no causal organism, but appears to be associated with the metabolism of the apple and for this reason is known as a physiological disorder. It appears on mature fruits, occasionally in the orchard, but most commonly after the fruit has been harvested, making its appearance during storage and on the market. The disease affects only certain varieties. The Jonathan and Esopus, both red varieties, are the most susceptible. Beach and Clark (2) working on the storage of New York apples in 1904, mentioned that Jonathan in storage usually shows dark spots on the skin after January 1. Scott (10) reported the disorder in 1911 on Jonathan and noticed at that time there were more spots on the red side of the apple than on the unblushed side. Later investigators have also reported the disease principally on red varieties, upon the deepest colored specimens, and further, upon the blush side of these fruits. Brooks and Cooley (3) point out that Jonathan spot is confined in its initial stages to the color bearing cells of the skin. In addition to the disease being associated with the red color of the fruit, it is favored by high temperatures, high humidity, and over maturity (8). The study that is presented here deals particularly with the relationship of the red color to Jonathan spot.

NATURE OF RED COLOR

Since the disease makes its appearance in the color bearing cells (3), a brief consideration of the nature of the red color in apples is of interest. Overholser (7) concluded that the color in red apples,

purple grapes, and similar fruits studied, is due to a group of pigments known as anthocyanins. This red pigment was found to be in solution in the cell sap, and was largely in the upper 3 or 4 layers. At this point it is of interest to note that the spot extends only a few cell layers into the apple, and is primarily a skin disease. Onslow (6) reports that the pigment is usually found in plants as glucosides, aromatic in formation, containing hydroxyl groups that are often replaced by sugars. A solution of the pigment is colored according to the reaction; red in presence of acid and blue when the medium is made alkaline. Magness (4) described the changes in color of the apple associated with ripening. The chlorophyll and red pigment is very abundant below the epidermis sometimes to a depth of 10 layers. As the red pigment develops, it apparently replaces the chlorophyll, being developed in the same cells as the chlorophyll.

Microscopical Examination of Tissue

In the study presented here, a microscopical examination was made of the apple skin. Cells full of red pigment could be seen in the subepidermis of the Jonathan apple. When sections through spotted tissue were observed, the color of the pigment was not red, but here and there could be seen cells whose contents were of a darker color. Upon magnification and with intense light, this color was found to be a bluish brown. Microscopically it appeared black, giving the typical color of Jonathan spot, as seen on the blush side of a well colored specimen. Martin, under whose direction the work was done, mentioned that certain varieties of beans which appeared black, were really blue when the cells were observed under sufficient magnification.

Onslow (6) states that the solution of anthocyanin turns from red, under acid conditions, to blue under alkaline conditions. Dilute HCl applied to the apple tissue while under observation with the microscope, changed the bluish color of affected cells to red. Dilute NH_4OH turned all red cells to blue A second application of HCl again changed the bluish color to red. Repeated trials gave the same results.

Treatment of Entire Apples with Alkali and Acid

Entire apples were subjected to NH_4OH vapor under a bell jar. They developed bluish black spots at once. These spots were similar to Jonathan spot, but were more intense in color. They began at the lenticels and spread quickly. In 20 minutes the apples assumed a deep bluish black color. Norton (5) in 1913 produced spots artificially with NH_3 which led him to assume that the escape of NH_3 gas in storage chambers was the cause of Jonathan spot. This theory was later disproved. However, Norton did not report changing the color of the entire apple or did he associate this color change with change in reaction of the red pigment.

The bluish black color of apples caused by treatment with NH_4OH, changed to red about 12 hours from the time they were removed from

the bell jar and exposed to ordinary room conditions. No visible damage had been done to the fruit by the treatment. Evidently the acid of the cortex region neutralized the alkaline effect of the alkali, bringing back the original color of the pigment.

An atmosphere saturated with HCl vapor hastened the change of the blue color back to red. The red color appeared first at the lenticles and spread rapidly. Severely spotted apples were treated overnight in this atmosphere. The black spots changed to a red color, but they were still somewhat darker colored than the surrounding area. The treatment softened the apples and caused the red color to permeate the flesh to a depth of about one-eighth inch.

H-ion Determination

To verify the theory that these color changes could be explained from a standpoint of change in reaction, H-ion determinations were made of certain tissues. The colorimetric method was used since the amount of material in the region examined was small, making it impractical to attempt to extract the juice and use the more accurate electrometric method.

Sections were made through the spotted and normal regions of the Jonathan apple and various indicators applied. In the table of PH values, 7.0 is taken as neutrality, alkalinity ranges from 7.0 to 14.0 and acidity from 7.0 to 0. The more acid the substance (active acid), the lower will be the PH value. The average PH value of affected tissue was 4.7 and of normal tissue PH 3.8. This difference in PH indicates there is a loss in acid in the blackened, spotted region. The loss in acid in this area often extends one-fourth inch into the flesh. No visible difference between this tissue beneath the spot and surrounding tissue is noticed until the indicator is applied.

The PH value was taken of the sub-epidermis tissue of a light red apple before it was subjected to NH_3 vapor. This value was PH 3.7. After the apple was treated with NH_3 vapor, it became blue in color. The PH value was again taken and found to be PH 4.5. Upon standing 16 hours, the color of the apples changed back to red, and the PH value again became about 3.7.

The results of these H-ion determinations upon tissue blackened by Jonathan spot, and tissue changed from red to blue by an alkali, verified the supposition that the red pigment changes to blue when the color bearing tissue becomes less acid.

A crude extract of the pigment was made from the peels of Jonathan apples after the method used by Anderson (1) with grape pigments at the New York Station. The red extract could be changed from red to rose, straw, blue and finally amber color, by additional amounts of NaOH. These changes occurred between PH 3.8 and 7.2. It is of interest to note that the red color changes to blue even if the reaction is not alkaline, but only less acid. The pigment in the natural state in the apple might be expected to become less acid during the storage season, but it does not seem probable that in a fruit as acid as an apple, it would be found in an alkaline condition.

Conclusions

The conclusions drawn from this study are that the red color of the apple can be changed to blue by making it less acid; that such a condition of acid deficiency is found in the spotted region, which accounts for the bluish black color of Jonathan spot.

Practical Application

Since Jonathan spot appears to be a disorder primarily of the color bearing region, it is suggested that the acidity of this region of the apple may be maintained by the use of paper wrappers impregnated with various harmless acids. If this can be done, there is reason to believe that the red color can be preserved and the undesirable, black-colored spots be prevented. Several harmless acids, such as boric and others used as impregnators for tissue wraps, are being tried during the present season to determine if during the process of respiration, enough of these acids will gain entrance to the fruit to maintain the acidity of the few cell layers of color bearing tissue.

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Fruiting Habit of the Grape

By H. G. SWARTWOUT, *University of Missouri, Columbia, Mo.*

INVESTIGATIONS on the fruiting habit of the grape were begun at the Missouri Experiment Station in 1922. The object of these studies has been to determine the relative productiveness (1) of canes on the upper and on the lower wires of vines trained to the 4-arm Kniffin system; (2) of laterals, canes from two-year-old wood and canes from wood more than 2 years old; (3) of buds at nodes where moderately sized laterals had been produced and at nodes where no laterals or only weak laterals are found; (4) of buds at the different nodes along the canes, and (5) of buds at the bases of canes, or on old wood and at nodes on canes.

Ten varieties—Concord, Moore, Worden, Wyoming, Catawba, Niagara, Diamond, Etta, Elvira and Missouri Riesling—representing several groups of grape varieties, were chosen for study because of their commercial importance or because of a peculiarity in their fruiting habit. All vines were pruned to the 4-arm Kniffin system.

The general nature of the results has been the same for each of the 3 years, 1922, 1923 and 1924, that the work has been carried on. The data for 1923 are typical and are presented in condensed form in Tables I, II and III.

Comparisons have been made from the data so arranged that buds and canes were comparable in all respects except the one under investigation.

Discussion of Results

Upper canes and lower canes.—The shoots on upper canes for all varieties studied have been more productive, produced larger clusters and more clusters per shoot than shoots on lower canes. This has held node for node between upper and lower canes and for different kinds of canes. When barren shoots and eyes that failed to grow are considered, the difference is still greater. The increased difference is due almost entirely to eyes which failed to grow. Only occasionally was a shoot produced that did not bear fruit and on close examination all such barren shoots were found to come either from a secondary bud or from a lateral bud near the base of an injured shoot. With the exception of Niagara, which was high, especially in 1923, the percentage of unfruited nodes was about the same for the different varieties. In general one-fifth to one-fourth of the eyes left failed to produce fruit.

Canes from wood of different ages.—Well developed lateral canes have shown greater fruitfulness than canes arising from two-year-old or older wood. This is similar to the results obtained by Partridge (1) with the Concord in Michigan. The difference in productivity between laterals and primary canes, however, becomes less the smaller the lateral canes. The size of the clusters and the number of clusters per shoot were also greater on lateral canes than on primary canes.

TABLE I—AVERAGE TOTAL PRODUCTION AND SIZE OF CLUSTERS PRODUCED BY DIFFERENT CANE BUDS

Variety	Position of canes				Kind of canes						Character of nodes			
	Production in ounces		Size of clusters in ounces		Production in ounces			Size of clusters in ounces			Production in ounces		Size of clusters in ounces	
	Upper canes	Lower canes	Upper canes	Lower canes	Lateral canes	Canes from 2-year wood	Canes from old wood	Lateral canes	Canes from 2-year wood	Canes from old wood	Branched nodes	Unbranched nodes	Branched nodes	Unbranched nodes
Missouri Riesling	8.0	5.9	2.3	1.9	7.9	6.0	6.9	2.3	2.1	2.2	9.3	7.2	2.8	2.3
Etta	11.2	10.3	2.8	2.7	11.2	10.3	10.9	2.8	2.8	2.9	11.0	10.9	2.9	2.8
Elvira	8.7	7.0	2.1	2.0	9.2	6.4	8.1	2.1	2.0	2.0	9.4	8.9	2.1	2.1
Wyoming	6.4	5.8	1.8	1.6	6.3	5.6	6.5	1.9	1.5	1.7	8.1	6.9	2.1	1.8
Concord	9.9	7.2	3.9	3.1	9.5	7.7	8.5	3.6	3.3	3.6	11.1	8.8	4.1	3.6
Moore	8.0	5.4	4.1	2.8	7.4	6.2	6.6	3.5	3.3	3.6	8.1	6.7	4.3	3.4
Worden	10.9	9.8	4.8	4.1	11.6	9.0	10.6	4.1	3.9	5.4	12.2	10.1	4.9	4.4
Niagara	14.4	8.6	6.2	4.6	11.4	11.8	11.4	5.5	5.3	5.4	16.0	11.1	7.1	5.2
Diamond	10.6	7.3	5.3	4.5	10.5	7.6	8.9	5.8	4.8	4.2	11.2	7.7	5.8	4.6
Catawba	8.6	7.1	3.2	2.7	8.8	7.6	7.8	3.1	2.9	3.0	10.9	9.3	3.7	3.3

Contrary to the findings of Partridge (1) with the Concord, the Concord and all the other varieties studied at Missouri except Niagara produced more fruit on canes arising from wood more than 2 years of age than on canes arising from two-year-old wood (the previous season's fruit canes). These canes also produced in general larger clusters and a slightly greater number of clusters per shoot than canes from two-year-old wood. Most of the canes from old wood came from wood 3, 4 and 5 years of age. There was a tendency, though broken by a number of exceptions, toward decreased fruitfulness the older the wood from which the canes arose. Also, all canes from wood more than 5 years of age were found to be less fruitful than canes from two-year-old wood. The discrepancy between the results obtained by Partridge and those of this Station may, therefore, be due to a study of canes arising from wood not comparable in age.

Branched and unbranched nodes.—The terms branched and unbranched nodes are used here for convenience to refer respectively to nodes where moderately sized laterals (that is, laterals 6 to 18 inches long with a good sized leaf area) had been produced and nodes where no laterals or only weak laterals had been produced. Branched nodes were found to produce more fruit and larger clusters than unbranched nodes. This has obtained the 3 years that comparisons have been made between such nodes with but one exception, Elvira, which in 1923 bore clusters of the same average weight at branched and unbranched nodes. Data were not secured for nodes on overly large

TABLE II—Average Total Production and Average Size of Clusters Produced by Buds at the Different Nodes on Canes

Variety	Production and size of clusters in ounces	Nodes				
		1 and 2	3 and 4	5 and 6	7 and 8	9 and 10
Missouri Riesling	Production	5.2	6.1	6.9	7.0	6.5
	size of clusters	2.0	2.2	2.3	2.4	2.2
Etta	Production	7.9	11.2	10.7	11.1	11.3
	size of clusters	2.3	2.9	2.9	2.8	2.8
Elvira	Production	4.8	6.7	7.9	6.4	7.5
	size of clusters	1.4	1.7	1.9	1.9	2.2
Wyoming	Production	4.1	5.9	6.3	7.6	6.3
	size of clusters	1.3	1.5	1.6	1.9	1.7
Concord	Production	6.5	7.8	8.2	8.8	7.5
	size of clusters	2.8	3.3	3.7	3.5	3.3
Moore	Production	5.1	6.4	6.9	6.3	6.2
	size of clusters	2.6	3.3	3.7	3.7	3.4
Worden	Production	8.3	9.2	9.9	8.8	10.8
	size of clusters	3.4	3.9	4.2	5.1	4.9
Niagara	Production	9.0	9.9	11.6	12.4	12.0
	size of clusters	4.9	4.1	5.3	6.1	6.3
Diamond	Production	5.6	7.4	8.4	10.5	9.0
	size of clusters	3.7	4.5	4.7	5.9	5.1
Catawba	Production	5.6	6.7	7.6	7.4	7.7
	size of clusters	2.6	2.8	3.2	2.8	3.4

canes where laterals of good size had been developed, but observations have shown that less fruit of poorer quality was produced at such nodes than at unbranched nodes on medium sized canes. The greater fruitfulness which has been found for branched nodes fails to substantiate the statements of Keffer (2) and Maney (3) that buds at the bases of laterals are less well developed and are not as good fruit buds as buds where laterals do not appear.

Buds at the different nodes on the canes.—Data have been obtained for only one year on the relative fruitfulness of buds at the different nodes on canes but the results in general agree with those of Keffer (2) and Partridge (1), (4). All varieties have shown a region of low production at the basal ends of the canes. Production in general increased with each succeeding node from the base until with most of the varieties a region of maximum production varying somewhat with the variety was reached, after which production gradually decreased. Only canes 10 nodes in length were used and 3 varieties, Etta, Worden and Catawba, showed no region of maximum production within this range, the highest yield being found at nodes 9 and 10. The regions of maximum production for the different varieties under the conditions of the experiment were as follows: Missouri Riesling, nodes 7–8; Elvira, nodes 5 6; Wyoming, nodes 7–8; Concord, nodes 7–8; Moore, nodes 5-6; Niagara, nodes 7 8; Diamond, nodes 7–8.

The average size of the clusters produced at the different nodes followed the same general order as the average yield per shoot.

TABLE III—YIELD AND AVERAGE SIZE OF CLUSTERS PRODUCED BY VINES PRUNED TO BASAL NODES AND VINES PRUNED TO FOUR CANES

Variety	Yield per vine in pounds		Average weight of clusters in ounces	
	Vines pruned to basal nodes	Vines pruned to canes	Vines pruned to basal nodes	Vines pruned to canes
Missouri Riesling	21.4	21.5	1.7	2.1
Etta	21.1	24.4	2.0	2.8
Elvira	10.1	14.8	1.3	2.0
Wyoming	25.7	25.5	1.5	1.7
Concord	6.0	20.6	1.4	3.5
Moore	5.2	14.2	2.7	3.5
Worden	9.8	22.5	3.6	4.4
Catawba	12.3	19.5	2.0	2.9
Niagara	14.9	24.3	3.8	5.2
Diamond	6.5	12.6	3.3	5.1

Adventitious buds.—The small buds at the bases of canes, and on old wood normally remain dormant but when forced into growth some of the buds produce fruiting shoots. To determine the fruiting capacity of these adventitious buds a few vines of each variety were pruned to leave two-year-old wood (the previous year's fruit canes) instead of canes as fruit wood. All canes were cut off back of the first node, care being taken not to injure the buds at the bases of the

canes. The vines were pruned to the 4-arm Kniffin system and approximately the same amount of wood was left as when the vines were pruned to canes. The amount of fruit and quality of the clusters produced by these vines were found to vary considerably with the variety. According to their behavior they can be grouped into 3 classes. First, Missouri Riesling, Etta, Elvira and Wyoming which were highly productive, the amount of fruit being almost and at times as great as that produced by vines pruned to canes; second, Moore, Concord and Worden which were comparatively unproductive; and third, Diamond, Niagara and Catawba which were intermediate and with which the amount of fruit produced by adventitious buds varied from year to year. The most of the fruit was produced by the buds at the bases of canes. Rarely did shoots coming directly from very old wood bear fruit.

The clusters produced by adventitious buds were in every instance smaller than those borne by shoots from node buds. Their average weight was roughly one-half to three-fourths that of cane produced clusters.

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Some Effects of Fruiting on the Growth of Grape Vines

By W. H. Chandler, *Berkeley, Calif.*, and A. J. Heinicke, *Ithaca, N. Y.*

It IS known that heavily fruiting trees or vines tend to make less growth than others. Some have attributed the fruiting to the weak growth rather than the weak growth to the fruiting. However, in some cases at least, weak growth results from the fruiting. Pickering (1916) found the heavy fruiting of dwarf apple trees that were not pruned at planting greatly to reduce the amount of growth made, as compared with trees pruned when planted. At Cornell University (1923) it was found that healthy trees with an abundant soil nitrate supply made much less trunk growth in a year of a heavy crop than in a year when no crop was being borne. Alternate bearing trees made the larger trunk growth in their "off years;" and annual bearing trees made a larger trunk growth in years when a heavy bloom was killed by frost than in years when a heavy crop was borne. More direct and conclusive results were obtained by Murneek (1925)

who found the growth of tomato plants greatly increased if the blossoms were removed, and by Mason (1921) who found the same true with cotton plants. At Cornell University work was begun with apples in 1917 and with grapes in 1918 to study the effect of removal of the blossoms on the dry weight increase of the different parts of the plants. Winter injury to the blossom buds would have prevented a crop of grapes in 1925, and so the plants were dug up in the spring of 1925. It is with these grape vines that this report is concerned.

Material and Method

The grape vines used were 13 Concord planted in the spring of 1918, 25 Concord and 25 Delaware planted in 1920. Several of the vines planted in 1920 died and others made unsatisfactory growth, 22 of these Concord and 10 of the Delaware being used in this report. Some of the vines were pruned to the Kniffin system and some were left unpruned, the trellises being made high enough to have all the foliage well exposed to the sunlight.

With half of the pruned vines and half of the unpruned ones the blossom clusters were removed while they were very small.

A record was kept of the leaf surface each year, the leaves being counted and collections of leaves from each plant being measured with a planimeter. The average area thus obtained for each plant each year was multiplied by the number of leaves to obtain the total leaf surface for the year.

The weight of prunings and of fruit borne each year was recorded together with the number of blossom clusters removed and of fruit clusters borne. And when the vines were dug up in 1925 the weight of the roots and of the tops was recorded separately. The pruning had been done before the vines were dug in 1925; but the weight of the 1925 prunings was added to that of the vines when dug.

Moisture determinations were made of the prunings and of the fruit; and when the vines were dug moisture determinations were made for the roots and for wood of the different ages, this having been weighed separately. The dry weight of a given number of blossom clusters was also determined. It was thus possible to express everything in terms of dry weight.

Results

With the unpruned vines it was evident after the first heavy crop that fruiting was reducing the amount of growth; with the pruned ones there was no difference that was evident to an observer. Table I shows the average green weight of roots and tops of pruned and unpruned vines that had fruited and that had had the blossoms removed.

With Delaware the vines were variable; and it is not certain from this table whether or not fruiting reduced the growth of the average Delaware vine. The same is true of the pruned Concord vines. With the unpruned Concord vines there seems certainly to have been a considerable reduction in growth of root and top due to fruiting;

TABLE I—Green Weight of Roots and Tops of Fruiting Grape Vines and of Vines from which the Blossoms were Removed

Variety	Treatment	Weight of roots in pounds	Weight of tops in pounds
Concord planted 1918. Three plants having each treatment.	Pruned fruited.	3.77	4.57
	Pruned blossoms removed	3.60	5.06
	Unpruned fruited.	4.30	7.85
	Unpruned blossoms removed.	7.40	12.25
Concord planted 1920. Five plants having each treatment.	Pruned fruited.	2.15	2.31
	Pruned blossoms removed.	2.97	3.64
	Unpruned fruited.	2.88	4.07
	Unpruned blossoms removed.	4.70	6.13
Delaware planted 1920. Two to 3 plants having each treatment.	Pruned fruited.	1.50	1.99
	Pruned blossoms removed.	1.75	2.08
	Unpruned fruited.	1.28	2.26
	Unpruned blossoms removed.	1.38	2.54

Note: By weight of tops is meant the actual size of the tops at the end of the season of 1924. The weight of prunings before that time is not included.

the reduction in top growth being about 33 per cent to 36 per cent and the reduction in root growth being about 39 per cent to 42 per cent. Since the heavy crops were borne only during the last year with the vines planted in 1920, and only during the last 2 years with the vines planted in 1918, much of the total growth being made before fruiting began, it is evident that the reduction in growth during the fruiting years was rather large.

It was, of course, not possible to obtain any direct measure of the size of the vines from year to year; but records of the leaf surface give a somewhat accurate indirect measure. In table II is shown the average leaf surface, each year, of the vines having each treatment. Except with the pruned Delaware there is a tendency for the increase in leaf surface during the last year to be relatively greater with the vines having the blossoms removed than with the fruiting vines.

Of course, the dry weight of the roots, top, pruning, fruit, flowers and leaves, after deducting the small amount of material from the soil, does not represent all the material elaborated in the leaves; an unknown amount of it is used in respiration. It has often been said that seed formation exerts a "devitalizing effect" on the plant. One might mean by a "devitalizing effect" that more energy is required, and, therefore, more food is used in respiration, to form a given dry weight of seed than to form as great a weight of other tissue. It would seem that a record of the total residue of dry matter to a given leaf area with fruiting and non-fruiting vines might give a suggestion as to whether more or less of the product of photosynthesis is used for respiration in the production of fruit, including seed, than in the production of the other tissue of the plant. In table III is shown the residue of dry matter as roots, top, prunings, fruit and blossoms in pounds to 1000 square feet of leaf surface borne by the vine.

TABLE II—AVERAGE LEAF SURFACE BY YEARS OF FRUITING GRAPE VINES AND OF VINES FROM WHICH THE BLOSSOMS WERE REMOVED

Variety	Treatment	1918 Square feet	1919 Square feet	1920 Square feet	1921 Square feet	1922 Square feet	1923 Square feet	1924 Square feet
Concord planted 1918	Unpruned, fruiting	0.20	0.44	3.7	17.0	84	176	340
	Unpruned, blossoms removed	0.17	0.6	3.6	20.0	80	151	472
	Pruned, fruiting	0.20	0.9	7.1	25.0	90	131	200
	Pruned, blossoms removed	0.43	0.7	5.0	21.0	67	114	224
Concord planted 1920	Unpruned, fruiting	—	—	1.0	6.8	36	99	165
	Unpruned, blossoms removed	—	—	1.03	6.6	41	101	202
	Pruned, fruiting	—	—	0.72	5.0	27	53	95
	Pruned, blossoms removed	—	—	0.84	4.9	31	75	137
Delaware planted 1920	Unpruned, fruiting	—	—	0.6	2.3	13	58	106
	Unpruned, blossoms removed	—	—	0.5	2.1	9	37	102
	Pruned, fruiting	—	—	0.5	3.7	8	42	112
	Pruned, blossoms removed	—	—	0.6	4.1	6	37	82

TABLE III—Dry Matter in Roots, Top, Prunings, Fruit and Blossom Clusters of Grape Vines Relative to the Amount of Leaf Surface Borne During the Lives of the Vines

Treatment	Dry matter in pounds to 1000 square feet of leaf surface					
	As roots	As tops	As prunings	As fruit	As blossoms removed	Total
Concord Grapes planted 1918.						
Unpruned, blossoms removed	4.29	8.55	—	0.85	0.10	13.79
Unpruned, fruited	2.81	6.52	—	13.63	—	22.97
Pruned, blossoms removed	3.67	5.75	4.31	0.09	0.02	13.83
Pruned, fruited	3.49	5.06	4.48	8.96	—	21.98
Concord Grapes planted 1920						
Unpruned, blossoms removed	5.91	8.18	—	0.68	0.07	14.87
Unpruned, fruited	4.01	6.28	—	15.76	—	25.30
Pruned, blossoms removed	5.87	7.44	3.11	0.06	0.02	16.50
Pruned, fruited	5.51	6.74	3.77	10.84	—	26.86
Delaware Grapes planted 1920						
Unpruned, blossoms removed	4.26	7.25	—	1.02	0.08	12.60
Unpruned, fruited	3.25	5.74	—	16.86	—	25.85
Pruned, blossoms removed	5.83	6.77	1.98	0.06	0.01	14.66
Pruned, fruited	4.39	6.53	1.79	7.68	—	20.39

All unpruned vines fruiting have reduced the residue of dry matter as root and as top from a given leaf area; the reduction being greater with roots than with tops. With the pruned vines there was much less reduction in the root and top growth, relative to a given leaf area, than with the unpruned vines. This may be because in each case there was a considerably greater leaf surface in proportion to the amount of dry matter in the fruit. Thus with the pruned vines the dry matter in the fruit to 1000 square feet of leaf surface was 7.68 to 10.84 pounds; while that with unpruned vines was 13.63 to 16.86 pounds. This, of course, is due to the fact that with the pruned vines the shoots were much longer and each had more leaves beyond the distal cluster of fruit.

However, the striking feature of the table is the fact that the total residue of dry matter (not including that in the leaves) is much greater with the fruiting vines than with the vines having the blossoms removed. With the Concord vines planted in 1918 the differences are probably considerably greater than the figures in the table indicate, for in 1924 most of the fruit from these vines was stolen and with each vine the crop, which was known to be large, was estimated at the minimum that it could have been.

There is a defect in this table in that the dry weight of a given area of leaves at the time of leaf fall, from fruiting and from non-fruiting vines, was not determined. Such determinations were to have been made in 1925 if the vines had not been dug. However, at the University of California in November, 1925, determinations of the areas and dry weights were made with collections of leaves from non-fruiting vines of Delaware and of Pierce, a variety resembling Concord but apparently with thicker leaves. With Delaware the dry matter in 1000 square feet of leaf surface was 10 to 11 and with Pierce 15 to 16 pounds. Certainly the dry matter in leaves of fruiting vines, if any less, could not be enough less nearly to account for the much greater total residue of dry matter as root, top and fruit to a given leaf area with the fruiting vines. It was not feasible to count the leaves twice during a summer. Perhaps a part of the reduced leaf surface of the fruiting vines may be explained by an earlier cessation of growth of the fruiting canes. In the climate of Ithaca most of the leaves of grape vines remain until they are killed by frost; and so, if the canes on fruiting vines cease growing earlier than those on non-fruiting vines, the average leaf on a fruiting vine will live a little longer than the average leaf on a vine with the blossoms removed. However, it is almost certain that with a pruned vine, whether it fruits or not, a much greater percentage of the leaf surface must be formed late in the summer than with an unpruned vine having the blossoms removed. And yet there is no significant difference in the dry matter residue from a given leaf surface of pruned and unpruned vines. It seems probable that not much of the difference in dry matter residue from a given leaf surface of fruiting and non-fruiting vines can be explained by a difference in the average length of life of the leaves. There is chlorophyl in the fruit; and some material

must be synthesized there, but, it seems probable, not nearly enough to account for all the difference in total dry matter residue between fruiting vines and vines with the blossoms removed. It seems that this difference must indicate either that less material is used in respiration to form a given dry weight of fruit than of wood and roots, or else that a rapid removal of materials from the leaves to form the fruits makes possible a more rapid photosynthesis.

Summary

With fruiting grape vines the growth of roots and tops was less than with vines from which the blossoms were removed; the difference being relatively greater with the roots than with the tops.

The total residue of dry matter from a given leaf area was much greater with fruiting vines than with vines from which the blossoms were removed. It seems that either less material must be used in respiration for a given dry weight of fruit than for the same dry weight of other tissue or the removal of material from the leaves to the fruits must tend to increase photosynthesis.

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Some Effects of Pruning on Grape Production

By J. H. Clark, *Agricultural Experiment Station, New Brunswick, N. J.*

GRAPE pruning has been practiced for so many years with such little variation that there has been some tendency among growers to prune by formula, treating each vine as nearly alike as possible. A few growers on the other hand have tried to give the vine treatment suitable to its individuality and to select canes which they thought to be of the most productive type. The basis for such treatment had been merely personal ideas strengthened by observation, often faulty, until the matter became the subject of investigation by horticulturists. Papers by various authors have shown that extremely long or short canes, canes with extra large or extra small diameters

and canes with very long or very short internodes are on the average apt to be less fruitful than canes of medium length, diameter and length of internode. The purpose of this paper is to present additional data on the relationship of original length of cane to production, especially with reference to any possible influence of degree of pruning.

The varieties on which the present report is based are Concord and Brighton. The vineyard, located at New Brunswick, N. J., was planted in 1917, on a slightly rolling site where the prevailing soil type is a rather uniform medium sandy loam. The plants themselves are quite uniform while any showing much deviation from the average were left out when the experiment was started.

Several pruning treatments have been carried out, the primary object being to determine as nearly as possible the optimum pruning treatment for vigorous vines of these 2 varieties on soil of average fertility in central New Jersey. Incidentally the 2 years' results now at hand are too meager to warrant recommendations as to severity of pruning. However, enough figures are available to give some idea of the type of cane likely to be most fruitful under these particular conditions. Owing to the small number of plants per treatment, 5 or 10 of each variety, it was obviously necessary to keep very detailed records if any significant results were to be secured. Accordingly the following points have been included in the data obtained: weight of prunings from entire plant, length of cane and number of buds before pruning; diameter of cane, average length of first 10 internodes and yield per cane and per bud by weight and number of clusters. The pruning treatments are shown in Table I.

In tabulating the results secured in order to determine the relationship of original length of cane to fruitfulness, canes were put in 1 of 4 classes, depending on their length before pruning. The canes of any 1 vine were on the average fairly well distributed among the 4 classes. The use of 1 foot classes instead of 2 would not have changed the results materially and would have decreased the already small number of canes per class. Canes in the "under 5 foot" class averaged about four feet in length and in only 1 or 2 cases were individuals less than 3 feet long. The "over 9 foot" class averaged about 11 feet, some individuals being as much as 19 feet long although few were over 13 feet. The distribution of the canes in the other 2 classes was quite uniform in most cases so that the average would be close to 6 feet in one and 8 feet in the other.

Table I includes data for 2 varieties over a period of 2 years, secured from vines pruned to 24 up to 72 buds (including 1 two-bud spur for each cane left at pruning time) and bearing canes from 6 to 20 buds in length. During the blooming season in 1924 the weather was cool and rainy while the blossoming period in 1925 was hot and dry. Brighton set very well both years but Concord produced ragged bunches each year and especially so in 1925. The results are grouped according to year, variety and pruning treatment.

A study of the data will show that in only 2 out of 28 groups did

the "under 5 foot" class outyield the other classes and in 1 of these the class average was based on only 1 cane. In 9 groups the 5 to 7 foot class outyielded the other 3. In 12 groups the 7 to 9 foot class was most productive and in 4 groups the "over 9 foot" class outyielded the others. In one case the yield was the same in the 7 to 9 foot class and "over 9 foot" class.

Table II gives a summary of the mean yield per bud for canes in each class, all canes of each variety being grouped by years. In this table, in 3 out of 4 cases, the 7 to 9 foot class produced the most fruit and in 1 instance the 5 to 7 foot class proved most productive. This would indicate that under the conditions of this experiment the optimum length of cane is somewhere between 5 and 9 feet and probably, on the average, between 7 and 9 feet. These figures obtained in New Jersey differ a little from those secured in Maryland by Schrader (2) as he found the 4 to 5 foot class to be most productive although the 5 to 6 foot class produced almost as much and yielded larger bunches. He suggests that the canes that are likely to be most productive are those which are moderately vegetative for the vine in question. Perhaps the most noteworthy thing shown by the data in these tables is the comparatively high yield of the long canes. Although not yielding as much as slightly shorter ones, the extra long type would hardly seem to justify its reputation for unfruitfulness.

Apparently the number of buds left at pruning time does not affect the *relative* fruitfulness of canes of various original lengths. On Concord vines pruned to from 12 to 20 buds per cane, the most productive type of cane seemed, during the season of 1925, to include those having an original length of over 9 feet. This tendency for long canes to be more productive than shorter ones when a large number of buds is left per cane is not evident enough to indicate that a different type of cane should be chosen if it is to be pruned to 8 buds than would be desirable if 16 buds were to be left. In fact we should not expect such a difference to exist unless there might be differences in the optimum points of production on canes of varying original lengths. According to Schrader (2) the high producing buds are located at about the same point on a cane regardless of the original length of the cane. If the point of optimum production were further from the base in the case of a long cane than is true with a short one, then there might be some reason for choosing extra long canes where as many as 15 to 20 buds per cane are to be left at pruning time. Partridge (1), without presenting data, states that the decline in productivity toward the tip is more rapid in the case of the smaller canes than in the quarter inch or large sized ones.

If the size of the crop during any particular year has any effect on relative fruitfulness of different cane types during that year, it should have shown up during 1924 and 1925. All varieties in the experimental vineyard at New Brunswick and in fact in most New Jersey vineyards produced much lighter crops in 1925 than in 1924. No consistant differences appear, however, which could be taken to indicate a seasonal influence on productive cane type.

The data do not indicate that the number of buds left on the vine at pruning time has any appreciable effect on the relative fruitfulness of canes of different original lengths. That is if a grower were going to prune a vine to 24 buds he should choose the same type of canes he would select if he were going to prune it to 72 buds.

The diameter of cane has been frequently considered as a measure of the fruitfulness of the cane. It may furnish a better indication than length of cane, but it would seem to be easier for the grower to choose canes by length than diameter since canes varying a foot in length are apt to vary less than two-hundredths of an inch in diameter. In this experiment the diameter of cane has proven to be roughly correlated with length. For instance the average diameter of cane for each length-class in the group of Concord vines pruned to the Munson system and carrying 4 eight-bud canes is as follows for 1924, .25 inch for the "under 5 foot" class, .26 inch for the 5 to 7 foot class, .28 inch for the 7 to 9 foot class and .32 inch for the "over 9 foot" class: for the year 1925, the average diameters were .26, .28, .33, and .35 inch respectively.

Length of internode has also been used as an indicator of probable fruitfulness of a cane, both alone and in combination with diameter of cane. The average length of the first 10 internodes was computed for each cane in this experiment. This figure is also roughly correlated with length of cane although long canes with relatively short internodes and short canes with long internodes are occasionally found. An inspection of the data without applying statistical methods does not indicate that such exceptional canes vary greatly in production from canes of the same length having average diameters and internode lengths.

There was very little difference in percentage of buds starting growth on long and short canes. Under some treatments the longer canes had more buds failing to start while in other groups the opposite was true.

With regard to pruning recommendations, it would seem desirable before such recommendations are made, that some relationship be established if possible between growth and vigor of the individual vine and relative production of different cane types.

Conclusions

1. Under the conditions prevailing in this experiment, canes of 7 to 9 feet in original length were on the average more productive than longer or shorter ones.
2. The data do not indicate that a different type of cane should be selected where 8 buds are to be left after pruning than would be selected where as many as 20 buds per cane are to be left.
3. The data do not indicate that a different type of cane should be selected for a vine that is to be pruned severely than should be selected if that vine were to be pruned lightly.
4. Apparently the type of cane which is most productive in a heavy crop year will be most productive in a light crop year.

5. While diameter of cane and length of internode are not considered in the tables presented, they are roughly proportional to original length of cane.

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(1) Partridge, N. L. "Profitable Pruning of the Concord Grape." Mich. Sp. Bul. 141, Jan. 1925.

(2) Schrader, A. L. "Growth Studies of the Concord Grape." Proc. Amer. Soc. Hort. Sci. 1923. pp. 116–122.

Growth and Yield of Concord Grape Vines

By N. L. Partridge, *Michigan State College, East Lansing, Mich.*

The vines from which the following results were obtained were the same ones used in the fertilizer tests made in 2 Van Buren county vineyards of quite diverse soil types. (1) The first vineyard is on a medium loam soil that is naturally fertile. This vineyard was comparatively vigorous at the time these tests were started, though there are other vineyards in the county that are more vigorous. The second is on a sandier, less fertile soil and its vines were making a rather weak growth at the time that the tests were commenced. The first records were obtained from the loam vineyard in 1921 and from the sandy vineyard in 1923.

The measure of growth used is the weight of the prunings obtained from the vine, after any wood more than 2 years old has been removed. This method of measuring growth has been discussed previously (2), and although it is perhaps not the best measurement possible, it seems to be as accurate as is practicable where a considerable number of vines is to be studied.

The results presented were obtained by considering the data obtained from all the vines in these blocks, no matter what fertilizer treatment they received. Tables* were compiled for each of the 3 crops studied in each vineyard, separating the vines by fertilizer treatments and pruning weights. Although in some years there are small significant differences between the yields of fertilized and unfertilized vines, particularly in the case of the weaker ones in the sandy vineyard, the main effect of the fertilizer applied, wherever it has proved of value in causing a larger yield, has been to increase the vigor of the vine. Consequently, the combination of all fertilizer treatments has been considered justifiable for this study. Some vines have been eliminated each year for various reasons, principally because of infection by the dead arm fungus or mechanical injury.

Grape vines should be pruned in accordance with their ability to produce fruit. Consequently, the pruning of these vines has been varied to correspond to their growth. A uniform scale of pruning has been used in both vineyards. Vines yielding 1 pound of prunings

*The author, for a reasonable time, will be pleased to supply mimeographed copies of a typical table to anyone interested in consulting it.

have been pruned to 30 buds; those with 2¼ pounds of prunings to 40 buds; and those with 3½ pounds of prunings to 50 buds, and so on. (This scale is not offered as a suggestion of the severity of pruning to be followed in all cases, but is merely a statement of the practice followed.)

The results show that the weight of prunings obtained from a vine will not furnish a sound basis for forcasting the yield of the vine unless its previous history is known. This is shown conclusively in Table I by comparing the results secured in the sandy vineyard during 1924, following a small crop, and in 1925, following a very large crop for that vineyard. In addition, results will vary from vineyard to vineyard where soil conditions vary widely, as has been shown previously (2), tables 21-24 inclusive. The fruiting of the vine depends upon many factors, many of which also influence the growth of the vine the preceding season, but, of course, some cannot, such as the seasonal and cultural conditions during the growth and maturing of the crop. The amount of the growth of the vine itself directly influences the fruiting of the vine the following year, due to its effect on the storage or utilization of the food materials manufactured by it. The relationship between vine growth and fruiting the following year is not a simple one but is complex. However, there is a considerable degree of correlation between the two, as is shown below.

TABLE I—RELATION OF POUNDS OF FRUIT PRODUCED TO POUNDS OF PRUNINGS REMOVED THE PRECEDING WINTER

Pounds of prunings	Pounds of fruit harvested					
	Loam vineyard			Sandy vineyard		
	1922*	1923	1924	1923**	1924	1925
0.1-0.4	10.4 (11)	10.2 (6)	4.1 (3)	1.9 (342)	7.5 (161)	2.0 (142)
0.5-0.9	14.1 (70)	11.7 (27)	8.7 (41)	4.3 (699)	14.2 (299)	4.3 (397)
1.0-1.4	16.7 (242)	16.5 (107)	12.8 (122)	7.5 (383)	19.5 (281)	6.2 (403)
1.5-1.9	19.6 (312)	19.8 (234)	15.8 (201)	10.8 (125)	22.3 (207)	7.6 (270)
2.0-2.4	22.5 (229)	21.8 (249)	17.8 (261)	13.0 (45)	24.4 (139)	9.3 (176)
2.5-2.9	23.6 (171)	23.1 (238)	20.2 (197)	14.5 (13)	25.7 (73)	10.7 (88)
3.0-3.4	25.3 (96)	23.9 (153)	22.9 (147)	18.0 (7)	28.0 (43)	11.5 (35)
3.5-3.9	25.1 (58)	24.3 (113)	24.2 (95)	16.3 (3)	29.6 (31)	13.5 (5)
4.0-4.4	29.0 (41)	25.1 (64)	24.5 (50)	35.2 (1)	26.0 (8)	20.1 (1)
4.5-4.9	27.4 (17)	30.3 (22)	25.2 (25)	———	39.2 (6)	———
5.0-5.4	30.6 (10)	27.8 (18)	30.5 (13)	———	———	———
5.5-5.9	34.5 (4)	30.5 (8)	24.7 (6)	———	15.4 (1)	———
6.0-6.4	———	33.5 (5)	31.7 (3)	———	———	———
6.5-6.9	———	26.4 (2)	———	———	———	———

Numbers in parenthesis indicate number of individuals from which average is calculated.
*In 1922 in the loam vineyard, the pruning weights were obtained to the nearest quarter pound. The group 0.5-0.9, for example includes pruning weights of three-fourths and 1 pound.
**In compiling the results for 1923 in the sandy vineyard the groups were made 0.1-0.5, 0.6-1.0, etc.

The data give results that confirm the conclusion previously reached from a study of much smaller populations (2), that there is an increase of yield as the vigor of the vine increases. The number of individuals in each class becomes much reduced as the vines be-

come very vigorous and, consequently, the averages calculated are more erratic, thus making it more difficult to determine the trend of the growth-yield curve.

The growth-yield curves obtained by graphing the data presented above are not straight-line curves. The curve rises more rapidly in the smaller values and tends to flatten out more or less as the vines become more vigorous. There is more similarity in the 3 loam vineyard curves than in those of the sandy vineyard, perhaps because the crop conditions were somewhat more uniform. The sandy vineyard has shown marked biennial bearing with over-crops in 1922 and 1924 and reduced yields in 1923 and 1925. The growth-yield curve in the "off" year more nearly approximates a straight-line curve than in the "on" year of the sandy vineyard or the more regular production of the loam vineyard. It is also noticeable that the most rapid increase of production as vigor is increased is to be found in the sandy vineyard when its vines were producing the over-crop of 1924. Another point of considerable significance is that those individuals producing the largest yields during each season and in each vineyard are invariably found to be vines of greater growth than the average.

Correlation tables† were prepared for each of the years and also for the three-year period for each of the vineyards studied. An examination indicates that there is a much closer correlation between growth and yield in the case of the weaker than the stronger vines. In the sandy vineyard in 1922, the coefficient of correlation between growth and yield is nearly twice as great when the vines below the mean vigor of the vineyard are considered alone than when those above the mean vigor are so considered. There seems to be somewhat more variability in fruitfulness on the part of the vines in the stronger growth classes.

The coefficient of correlation has been calculated for each of the years and vineyards studied, the results being as follows:

TABLE II—Correlation of Pounds of Fruit Produced to Pounds of Prunings Removed the Preceding Winter

	Loam vineyard			Sandy vineyard		
	1922	1923	1924	1923	1924	1925
Average, pounds of prunings..	2.05±.02	2.54±.02	2.46±.02	0.97±.02	1.40±.02	1.32±.01
σ Prunings.....	.97	1.02	.99	.97	.91	.73
Average, pounds of fruit......	20.9 ±.14	21.9 ±.13	18.8 ±.15	5.5 ±.07	18.7 ±.15	6.3 ±.07
σ Fruit.......	7.48	6.97	7.34	4.31	7.71	3.79
r............	0.52±.01	0.45±.01	0.59±.01	0.74±.01	0.76±.01	0.67±.01

†The author, for a reasonable time, will be pleased to supply mimeographed copies of these tables to anyone interested in consulting them.

It will be observed that the coefficient is higher in the case of the sandy vineyard than in the loam vineyard. This perhaps is due to the difference in the distribution of the two populations, a larger proportion of the vines of the former falling in the less vigorous groups than is the case with the loam vineyard. Coefficients of correlation were also calculated for the combined three-year period for each vineyard. These were 0.60 ± .01 for the loam vineyard and 0.85 ± .01 for the sandy vineyard. These figures are higher than the coefficient obtained for any 1 of the 3 years in the particular vineyard.

The data show the importance of increasing the vigor of the less vigorous vines and also explain the smaller returns to be expected to follow an equal increase of vegetation in the higher growth classes. The fact mentioned previously, that the use of fertilizer on these grapevines influences fruit yield mainly through its effect on growth should not be overlooked.

Citations

(1) Partridge, N. L. Commercial Fertilizers for Grapes. Mich. Agr. Exp. Sta. Quart. Bul. 7:98. 1925.

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Some Responses of the Grape to Pruning

By A. J. Winkler, *University Farm, Davis, Calif.*

This address in more complete form than presented to the Society will be published in "Hilgardia" by the California Agricultural Experiment Station.

Pollination Studies with Certain New York State Apple Varieties

By L. H. MacDaniels, *Cornell University, Ithaca, N. Y.*

THE sterility and inter-sterility of apple varieties although recognized as a factor in the set of fruit, have not been emphasized as a problem of any great practical importance in the fruit growing sections of New York State until comparatively recently. This has probably been due either to the fact that nearly all the early plantings were of such a mixed nature that satisfactory conditions for cross-pollination were provided, or that the varieties concerned were at least partially self-fertile, or possibly that failure to set good crops

in some cases was wrongly attributed entirely to the direct influence of the weather at blooming time, rather than in part to the self-sterility of certain varieties.

Within the last few years, however, the question of self-sterility and cross-pollination has been one of considerable interest among the growers of the state, doubtless due to the publicity it has received on the Pacific Coast and elsewhere, and also because in some of the newer plantings, single varieties, the pollen requirement of which were not well known, have been set out in large blocks. The present paper is a progress report of an attempt to find out the self-sterility and inter-sterility relationships under New York conditions, of some of the more important varieties which are being planted in the state at the present time. The fact that these same varieties are being worked upon elsewhere does not in any serious way argue against the carrying on of duplicate work at Ithaca, in that it is becoming increasingly plain that the same varieties behave quite differently as regards their ability to set fruit in different climates. For instance, from the grower's experience with large blocks of the Baldwin apple in Western New York it would seem that this variety must be self-fertile in that no pollination problem has appeared. On the other hand, Sax working in Maine (1) and Howlett in Ohio (unpublished) seem to find this variety largely self-sterile and worthless as a pollinizer. The chief interest in the whole problem, from the grower's standpoint, is to find out what varieties will be effective pollenizers for new plantings in different parts of the state.

The rather voluminous literature upon the subject of self-sterility and pollination has recently been brought together and summarized by Chandler (2) and Auchter (3) so that there is no reason for its discussion here. Suffice it to call attention again to the great complexity of the whole problem and the great number of variable factors involved. The mass of conflicting data on the self-sterility of apple varieties can be interpreted either on the basis of the number of variable factors concerned, or the very great experimental error in the methods used. Undoubtedly both interpretations are valid in part. Although the method of emasculation has given consistent results with some investigators, yet the technique is so critical as to make the widespread use of the method unsatisfactory if consistent results are expected. It is becoming increasingly evident also that the shading of the leaves of the pollinated spur with bags introduces an error that is practically impossible to evaluate. Such shading without much question upsets the nutritional relationships between the young fruits and the spur at the most critical period of fruit setting. Omitting the bags as done by Sax (1) would seem to be a very desirable procedure in avoiding this possibility of error if the emasculation method is to be used. Before this method is widely used, however, it is probably necessary to get more evidence as to the frequency with which bees visit flowers with their perianths removed.

In order to avoid the sources of error involved in emasculation and bagging, to use large numbers of flowers and to similate natural

field conditions in these experiments, the method of caging entire trees with a hive of bees was employed. It is felt that the results of this cage method are probably more reliable than the others from a practical standpoint. The cages, made by covering a wooden framework with mosquito netting, were completed on May 5, before any apple blossoms either in the orchard or in the vicinity had opened. A hive of bees was placed in each cage immediately so that none of the bees had access to apple blossoms before being placed in the cages. The 1925 blossoming season was very favorable for pollination at Ithaca, in that there were at least 6 days while the blossoms were open when the weather was sufficiently warm and bright to favor the flight of bees for from 3 to 6 hours each day. This was checked by a continuous record of temperature made by a recording thermometer and by observation. The bees were observed to be working on all these days and there can be no doubt but that the flowers on the caged trees received many more visits from bees than those of the uncaged trees.

The experience with the different trees was as follows:

McIntosh—tree L′ 2′. Tree 13 years old and had borne well previously. This tree was caged with a hive of bees and left undisturbed until after the petals fell. To find the number of blossoms the tree was divided into 4 parts as nearly equal as it was possible to estimate and the number of blossom clusters counted on one part. This number was multiplied by 4 to obtain the total number of clusters and the result by 6 to obtain the total number of flowers.

Total number of blossoms	14400
Number of fruits set and matured	130
Per cent set	0.9

McIntosh—tree K′, 2′. Tree of the same age as the preceding but somewhat more vigorous. This tree caged with bees which worked on the McIntosh bloom undisturbed until the tree was in full bloom, giving ample opportunity for the blossoms to be self-pollinated. At this time two branches of blossoms were enclosed in cheese cloth bags about 6 by 3 feet in size and Rhode Island Greening blossoms which were just beginning to open were introduced into the cage in tubs of water placed in front of the hive of bees. During the succeeding days there was ample opportunity for the bees to transfer pollen from the Rhode Island Greening blossoms to the McIntosh.

Number of flowers outside bags	15822
Number of fruits set	111
Per cent set	0.7
Number of flowers in bags	480
Number of fruits set	None

McIntosh. tree K′, 4′. Check. Open pollination. This tree was the same age as the preceding but somewhat larger and more vigorous. It bloomed heavily and set a normal crop as compared with other trees in the row. The number of blossoms was obtained

by counting all the blossom clusters on one large limb which by its relative size was estimated to be one-tenth of the entire tree. This count was multiplied by 10 to get total number of blossom clusters and the result by 6 to give the number of blossoms.

Total number of blossoms	42000
Fruits removed by thinning	1620
Fruits picked when mature	2473
Total fruits set	4093
Per cent set	9.7

Cortland, tree 10 years old. It had borne light crops for several years. The rather severe cutting of the tree for scion wood probably prevented heavier fruiting by reducing the amount of bloom. First bloom on tree May 12. Tree caged with bees which worked on flowers, self-pollinating them until May 15 at which time two-thirds of blossoms were open. At this time bags were put upon 2 branches of Cortland flowers and McIntosh flowers were introduced into the cage from the caged McIntosh tree which had not been exposed to cross-pollination with Rhode Island Greening. On May 19 a fresh supply of McIntosh flowers bearing abundant pollen was placed in the cage. The bees remained in the cage until the petals fell.

Total number of blossoms on Cortland tree outside bags	3900
Number of fruits set and matured	247
Per cent set	6.3
Number of blossoms in bags	450
Number of fruits set in bags	None

Baldwin. Two dwarf trees 6 years old which had fruited well previously were caged together and bees introduced into the cage. Bloom on all trees in the row was light because of it being their off year. Bees remained in cage until petals fell.

Tree 1.	Number of blossoms	420
	Number of fruits	45
	Per cent set	10.7
Tree 2.	Number of blossoms	720
	Number of fruits	87
	Per cent	12.1
Tree 3.	Check, open pollination	
	Number of blossoms	426
	Number of fruits	25
	Per cent set	5.9
Tree 4.	Check, open pollination	
	Total number of blossoms	438
	Total number of fruits	54
	Per cent set	12.3

It is, of course, recognized that the above data are based on a few trees only and represent the results of but a single year. Neverthe-

less, the number of blossoms involved is large as compared with that usually employed in hand pollination experiments and the method employed such that many of the unnatural conditions introduced in many pollination experiments are obviated. It is, therefore, felt that the results are at least suggestive of the following interpretation applicable under Ithaca conditions.

1. That the McIntosh is largely self-sterile—a condition found elsewhere also (1) (2).

2. That McIntosh and Rhode Island Greening appear to be intersterile. This, however, needs confirmation by further evidence. Sax (1) obtained a fairly good set on McIntosh with Rhode Island Greening pollen.

3. That Cortland is self-sterile, but may be pollinated with McIntosh although the per cent set was not large considering the light bloom. Press reports from the New York State Experiment Station at Geneva also state that McIntosh will pollinate Cortland, but that Cortland will not serve as a satisfactory pollinizer for McIntosh (4). No data have as yet been published.

4. That Baldwin, at least under the local conditions, is self-fertile or at least self-fruitful, a condition differing from that found in Maine (1) and Ohio, but as pointed out by Chandler (2) the same as that found in a number of other stations.

Attention should be called to the fact that no fruit set in the cheesecloth bags either on the McIntosh or the Cortland trees. Bees were observed working on these blossoms before they were bagged so that there can be no doubt but that they were self-pollinated. If the bagged flowers on the McIntosh tree K′ 2′ had set the same percentage of fruit as the self-pollinated tree L′ 2′, there would have been the possibility of 4 apples in the bags on this tree. Just as a matter of chance, however, it would be quite possible not to have fruit set on these particular flowers. Another explanation would be that the shade of the bags was sufficient to prevent a set of fruit. It is also quite possible that the failure of the Cortland flowers to set in bags is not particularly significant in showing the Cortland to be self-sterile although in this case the fruit spurs were more vigorous and the blossoms not so crowded as in the case of the McIntosh.

It should also be pointed out that the procedure of exposing blossoms in the cages to the visits of bees for the purpose of self-pollinating the check branches, and then introducing blossoms of other varieties to secure cross-pollination of the blossoms not bagged, is open to some objection in that the frequent visits of the bees might injure the stigmas mechanically so that they would cease to be receptive, or that the selfing of the stigmas might make them non-receptive to the foreign pollen because of chemical or other changes produced by the presence of the pollen, or the initiation of growth of the pollen on the selfed stigma before the foreign pollen was applied. This may account in part for the apparent incompatibility of the McIntosh and Rhode Island Greening. The objection would not be so applicable in the case of the Cortland-McIntosh cross because in

this case McIntosh pollen was introduced when a considerable number of Cortland blossoms were still unopened.

Number of Seeds in Self-Pollinated and Cross-Pollinated Fruits

As an additional check on the self-sterility or self-incompatibility of the Baldwin, McIntosh and Cortland apples, seed counts were made of the fruits of the caged trees and of fruits of the same varieties from open pollinated trees, except in the case of the Cortland where no check tree was available. These appear in the following table:

Variety	Treatment	Number Fruits Counted	Average Number Seeds Per Fruit
Baldwin			
Tree 1	Selfed	44	2.5
Tree 2	Selfed	55	2.8
Baldwin	Check	50	5.2
McIntosh	Selfed	50	2.1
McIntosh	Check	30	7.9
CortlandxMcIntosh		25	2.6

In the above tables it is evident that McIntosh and Baldwin when self-pollinated do not produce as large a number of seeds per fruit as when cross pollinated. A similar situation has been pointed out by Waite (6) for pears and also by Gowen (7) for Baldwin. In the latter case, however, only 4 selfed Baldwin fruits were examined. The fact that the selfed Baldwins set as heavy a crop as the checks in spite of the smaller number of seeds, might be taken to indicate that this variety has more than average ability to set fruit without many seeds per fruit, and hence is able to set good crops in spite of a greater or less degree of self-incompatibility. The number of seeds in the Cortland apples fertilized with McIntosh pollen indicates that the 2 varieties are no more compatible as regards seed production than is McIntosh selfed even though the per cent set was higher than in case of the selfed McIntosh. Although there were no fruits from open pollinated blossoms of the Cortland from which seed counts could be made for comparison, it can hardly be supposed that 2.6 seeds per fruit is a sufficient number to indicate a high degree of compatibility between the 2 varieties. Crandall (9) has shown that the average number of seeds per fruit under open pollinated conditions is 7.8 and that Collins which was the least productive of seeds gave an average of 4.09 seeds per fruit. The number of seeds in the Cortland fruits pollinated by McIntosh must thus be regarded as distinctly below normal.

Germination of Pollen

Supplementary to the field work with the cages, germination tests were carried on to determine the viability of the pollen from the trees concerned and also of some other varieties. The method used was that described by Brink (5) in which the pollen is germinated in

THE NUMBER OF FRUITS OF EACH VARIETY HAVING A GIVEN NUMBER OF SEEDS IS AS FOLLOWS

Variety	Treatment	Seeds per fruit													
		0	1	2	3	4	5	6	7	8	9	10	11	12	13
Baldwin Tree 1	Selfed	—	7	19	6	9	2	1	—	—	—	—	—	—	—
Tree 2	Selfed	—	6	20	14	7	6	2	—	—	—	—	—	—	—
Baldwin	Check	—	0	1	2	11	16	12	5	5	3	—	—	—	—
McIntosh	Selfed	—	24	13	5	5	4	1	—	—	—	—	—	—	—
McIntosh	Check	—	—	—	—	1	5	3	4	5	3	—	2	1	1
Cortland x McIntosh		4	2	7	4	5	1	1	1	—	—	—	—	—	—

petrie dishes on 1½ per cent agar containing 10 per cent commercial cane sugar and a trace of sterile yeast. The percentage germination was determined by counting all the grains in the microscope field (7.5 ocular, 16 mm. objective) on several different places on the agar plate, figuring percentage germination in each case and averaging the results.

The results of pollen germination are as follows: McIntosh, per cent germination 24. This represents the average of the counts on 2 lots of pollen from the caged tree germinated at 4 different temperatures. Highest germination obtained was 33 per cent, and lowest 17 per cent. About two-thirds of the pollen appeared imperfect in that the grains were shrunken and without protoplasmic contents. Practically all normal appearing grains germinated.

Baldwin, average percentage germination 9, highest percentage 13, lowest 4. The average represents 2 lots of pollen each from 2 different trees (1 tree caged, the other not) germinated at 4 different temperatures. Pollen of this variety behaved differently from that of the other varieties tried in that a large proportion of the grains were aborted and shrunken and many burst without making normal tube growth, or the tubes were misshapen and abnormal. Less bursting was observed at temperatures of 12° and 16°C. than at 24° and 28°C. From the behavior of this pollen upon the medium used it might be inferred that the medium was not favorable as to its osmotic concentration in that so many grains burst from what might be interpreted as an intake of water increasing the osmotic pressure. This question has been studied by Brink (5) who suggests this as a possibility although for the most part pollen seemed to be tolerant of rather wide ranges of osmotic concentration of the medium.

Rhode Island Greening, average percentage germination 13, highest 18, lowest 9. One lot of pollen from blossoms which were introduced into the McIntosh cage germinated at 4 different temperatures. There was a higher percentage of germination at 12° and 16°C. than at 24° and 28°. This variety showed a considerable proportion of imperfect pollen grains similar to that of the Baldwin. Fewer grains burst, however, than with that variety.

Cortland, 75 per cent germination at 28° C., 30 per cent at 22°C. These were separate lots of pollen taken on different days. The difference in percentage germination is probably not due to temperature differences.

Golden Delicious, average percentage germination 83, highest 89, lowest 66. The highest percentage germination and greatest growth were at room temperature, 22°C. The growth of the pollen tubes in this variety was remarkably vigorous. The groups of germinating pollen grains after 24 hours resembled tufts of fungous mycelium, the pollen tubes in many cases extending into the moist air of the petrie dish.

Delicious, percentage germination 89. Growth of pollen tubes very vigorous resembling those of the Golden Delicious in appearance.

Arkansas (Mammoth Black Twig), percentage germnaition 12. Many of the pollen grains were imperfect and the tubes made but poor growth as compared with Delicious pollen.

Germination tests were carried on with these last 3 varieties to test out the viability of the pollen produced under Ithaca conditions as compared with results elsewhere. In general there is very close agreement in that Delicious has been shown to produce abundant viable pollen (8) and Arkansas to be lacking in this regard (3).

The data obtained upon the different rates of pollen tube growth and percentage germination at different temperatures are too meager to be significant and are not given here in detail. It is suggested, however, that the pollen of different varieties may have different optimum temperatures for tube growth and hence varieties may vary in their efficiency as pollenizers under different weather conditions due to a differential effect of temperature upon the rate of tube growth.

The low percentage germination of the pollen of the Baldwin coupled with the fact that this variety appeared to be self-fertile in the case of the caged trees, indicates either that pollen of very low percentage germination is still sufficiently abundant in its absolute amount to affect satisfactory pollination, or that Baldwin is able to set fruit with few seeds and hence with what for another variety would be inadequate pollen, or that the media used in growing the pollen was not suitable for this variety and hence the percentage germination obtained was not a true index of the viability of the pollen. The bursting of the pollen grains and the irregular growth of the pollen tubes as indicated above would substantiate the last explanation. There is some evidence to show that varieties differ in the nature of the stigmatic fluid (8) for example its osmotic or hydrogen-ion concentration as well as in other characters. Media, therefore, that would give vigorous pollen tube growth and high percentage germination in the case of the Delicious, might be quite unsuited to optimum growth of the pollen of Baldwin. Such a statement, of course, needs additional data for confirmation.

The behavior of the Baldwin in the present case serves but to emphasize the fact already pointed out elsewhere (3) that the self-sterility or self-fertility of a variety may depend upon a very delicate adjustment of many factors. Self-sterility in most cases is not an absolute characteristic of a variety and on the basis of our present knowledge it is impossible to generalize on the behavior of a variety under all conditions. The effectiveness of the work on pollination problems in different parts of the country could be greatly increased by the formulation of, and agreement upon, some standard method in studying the problem by workers in this field. Until this is done results in this work will not be satisfactorily comparable.

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Pollen Development in the Apple with Special Reference to Chrosome Behavior

By J. S. SHOEMAKER, *University Farm, St. Paul, Minn.*

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Cross Fertilization of the Arkansas (Mammoth Black Twig) Apple

By E. C. AUCHTER and A. L. SCHRADER, *University of Maryland, College Park, Md.*

INTRODUCTION

THE Arkansas apple, because of its shy bearing, has rapidly been losing favor with commercial growers in many of the eastern states. Thus this complaint of shy bearing has become quite general from growers in southern Pennsylvania, Maryland, West Virginia, Virginia and Kentucky, where this variety is grown. Many growers, who have noticed that this variety has not responded with satisfactory crops to special pruning practices, special soil management treatments, or additional applications of nitrate fertilizers, and who have had it interplanted with other varieties, have become discouraged, and have topworked the trees to other varieties. Others, no doubt, have decided to follow this example if the trees can not be made to bear fruit.

It has not been a question of lack of fruit-bud formation or blossoming. In fact the trees form numerous fruit buds and generally blossom profusely each year. Shortly after blossoming, however, hopes for a crop begin to dwindle, when it is noted that practically no "set" has occurred.

Occasional orchards in this general region have been reported as bearing good yearly crops. Various explanations have been advanced in regard to such crops. The successful grower, probably at a state horticultural society meeting, would report that this variety needed unusually heavy fertilizer applications, extra early and thorough cultivation and large cover crops plowed under. The problem would appear solved until another successful orchardist, possibly from another state, would explain that the way he got crops was to keep his trees checked in growth. His recommendations of orchard culture and fertilization might be just opposite to the preceding recommendations.

Orchard Management Observations in Maryland

Realizing the fact that this variety had many desirable qualities such as vigorous tree growth, comparative resistance to many diseases, and fruit of good size and color which kept well in common or cold storage, the authors felt that a thorough study should at least be made, before approving the elimination of the variety from commercial orchards.

Their observations and experiments relative to special pruning practices, special soil management treatments and additional applications of nitrate fertilizers, previous to blossoming, resulted in much the same conclusions as the growers previously stated. Although an occasional orchard might set a little better, during one year, following special pruning and heavy nitrate applications, still the results were by no means consistent in the different orchards.

Although the spurs might be of desirable lengths and thickness and exposed to plenty of sunlight, still poor "sets" occurred.

Finally it was decided to make a thorough study of cross-pollination before giving up the problem. This had not been done before, because it was known that the variety in most cases was interplanted with other varieties. In a large percentage of these orchards, Grimes was the other variety planted. Stayman Winesap, York Imperial, Ben Davis and Rome Beauty also were often interplanted.

Cross Pollination Experiments, 1924

Results from Tree I: During 1924, the pollination experiments were all conducted on trees growing on the Experiment Station grounds at College Park.

Pollen from 14 varieties was collected from blossoms just before the petals opened. This pollen was ripened under uniform conditions and applied during the same morning, (May 5, 1924), to 1 heavily blossoming tree of moderate vigor. This tree was about 30 years old, growing in a cultivated orchard near other Arkansas trees. Near by were some Grimes, York Imperial and Smokehouse trees.

Since the Arkansas had always proven entirely self-sterile at the College during the preceding 5 years, when thousands of blossoms had been bagged, it was decided not to emasculate the blossoms in this main experiment. It was also felt that the conditions would thus more nearly equal natural conditions of cross-pollination by bees. As a result several thousand blossoms were covered when in the pink stage to protect from bees until the blossoms had opened and were ready to receive the pollen. After applying the pollen the blossoms were again bagged for a few days. Results are shown in Table I.

TABLE I—SET OF FRUIT ON ONE ARKANSAS TREE FROM THE APPLICATION OF POLLEN TAKEN FROM FOURTEEN VARIETIES

Variety cross	Number of blossoms crossed	Number of blossoms set	Per cent of blossoms set
Arkansas x Delicious	500	17	3.4
Arkansas x Jonathan	500	16	3.2
Arkansas x Hubbardston	500	14	2.8
Arkansas x Yellow Transparent	500	13	2.6
Arkansas x Wealthy	500	13	2.6
Arkansas x York Imperial	500	11	2.2
Arkansas x Red June	500	5	1.0
Arkansas x Northwestern Greening	500	3	0.6
Arkansas x McIntosh	500	1	0.2
Arkansas x Summer Rambo	500	0	0.0
Arkansas x Stayman Winesap	500	0	0.0
Arkansas x Grimes	500	0	0.0
Arkansas x Nero	500	0	0.0
Arkansas x Oldenburg	500	0	0.0
Arkansas x Selfed	500	0	0.0
Arkansas x Open Pollinated	1000	16	1.6

When set records were obtained we were surprised to find how many varieties had caused some fruit to set. It can be seen that the first 6 varieties caused a higher percentage to set than occurred under open-pollination conditions. In fact, twice as much set occurred where Delicious and Jonathan pollen was used. It will be recalled that this Arkansas tree was not far from other York Imperial and Smokehouse trees. However the York Imperial comes into full bloom from 4 to 5 days later than the Arkansas at College Park, and thus may account for the poorer open set compared to the York Imperial pollen results The York Imperial pollen had of course been ripened artificially as described above. Pollen from the nearby Smokehouse trees, if it reached the Arkansas, was apparently not as satisfactory as the first 6 listed.

We were especially surprised at the lack of set where Grimes pollen was used. A high percentage of the pollen of Grimes and also of Nero and Summer Rambo germinates readily in sugar solutions. Grimes, in previous work, Auchter (1), had proven especially good as a pollenizer for Stayman Winesap.

Results from Emasculated Blossoms: As a check on the above results 1500 blossoms were emasculated on the above tree and pollen of

3 varieties, Jonathan, Summer Rambo and Grimes, were placed on 500 blossoms each on May 5, 1924. No set resulted from Summer Rambo or Grimes, while Jonathan set one apple. Thus less set occurred with Jonathan where emasculation was first performed. Summer Rambo and Grimes gave no set as in the above case with unemasculated blossoms.

Results from Tree II: A young ten-year-old, vigorously growing Arkansas tree, which was blossoming heavily, was also used in the experiments. No emasculation was performed. Five hundred blossoms each were crossed with the following varieties: Delicious, Jonathan, Summer Rambo, Grimes, Stayman Winesap, Northwestern Greening, Yellow Transparent, McIntosh, Wealthy and Hubbardston. The following numbers of blossoms "set" in each case. One Delicious, two of Yellow Transparent, one of Wealthy, and five of Hubbardston. No set occurred with Summer Rambo, Grimes, Stayman Winesap, McIntosh or Jonathan. Five hundred selfed blossoms set no fruit and 1000 open pollinated blossoms set only three. Thus, although the blossoms on the tree set very poorly, as a whole it can be seen that the same high varieties as in Table I gave some set where they were used, except Jonathan and Northwestern Greening. Grimes failed again in this case.

Results From Tree III: An old Arkansas tree rather low in vigor and standing in sod was also used in these tests Nearby were Wealthy, Red Astrachan, Kinnaird, Grimes, and Gano trees In this case 8 pounds of nitrate of soda were applied to the ground on one side of the tree about 3 weeks before blossoming. At pollination time, 500 blossoms on the nitrated side and 500 on the check side, were crossed with Grimes pollen. Like numbers on both sides of the trees were crossed with Summer Rambo, Yellow Transparent and Oldenburg. Eight hundred and twelve blossoms were selfed on the nitrated side only. Five hundred blossoms on each side were counted for open pollination results. No blossoms set on either side where Summer Rambo, Grimes or Oldenburg pollen was used as in the case of the other 2 trees. Five blossoms set on the check side where Yellow Transparent pollen was used and none on the nitrated side. No fruit set under the selfed conditions, but 31 set on the nitrated side under open-pollinated conditions, and only 16 on the check side.

Although the nitrate did not affect the set where Yellow Transparent pollen was used except adversely, the "set" under open pollinated conditions was approximately twice as high where nitrate had been applied. It will be remembered that Wealthy pollen, which had proven good on Tree I, was available for open-pollination in this case. Thus where compatible pollen was available nitrate increased the set in one instance and not in the other in the case of this somewhat devitalized tree.

In summation of the 1924 work on 3 Arkansas trees, it can be seen that a total of 2500 crosses of Arkansas x Grimes resulted in no fruit being set. Likewise 2500 Arkansas x Summer Rambo crosses produced no fruit. Fifteen hundred crosses with Oldenburg were un-

successful. Twenty fruits set out of 2000 crosses with Yellow Transparent, 17 out of 500 Delicious, and 16 out of 2000 Jonathan.

Cross-Pollination Experiments, 1925

Results of the preceding year indicated that the problem of poor "setting" and thus shy bearing of the Arkansas might be one of cross-pollination. Of the varieties commonly grown as permanent trees, in this region, Delicious and Jonathan, which blossom at about the same time as Arkansas, seemed to give the highest sets. Other varieties such as Yellow Transparent and Wealthy, often used as fillers, also seemed to cause good sets. Red June was fair and York Imperial pollen, if it was available soon enough, proved capable of causing a fair set. Grimes, Summer Rambo and Oldenburg pollen on the other hand was apparently of no value when crossed on Arkansas.

It was decided to check up on some of these results in several different orchards located on different soils and in widely different parts of the state. Accordingly, cross-pollination experiments were carried on in the western part of the state near Hancock, in the central part near Sandy Springs, and in the northeastern part near Westminister. Similar tests were also conducted again at College Park. Not all of the varieties were used in all orchards, but an attempt was made to include Delicious, Grimes and Jonathan at each place. Results follow.

Parkhead Orchard Near Hancock: In this orchard Arkansas interplanted with York Imperial and Stayman Winesap, had never "set" a commercial crop. The trees were about 14 years old. The soil had been cultivated each year and cover crops had been plowed under. Previous investigations (1) have shown that Stayman Winesap and Arkansas are inter-sterile and York Imperial apparently blossomed too late to be entirely satisfactory for Arkansas.

TABLE II—Set of Fruit on Tree I

Variety cross	Number of blossoms crossed	Number of blossoms set	Per cent of blossoms set
Arkansas x Red June	85	39	45.90
Arkansas x Yellow Transparent	67	0	0.00
Arkansas x Grimes	150	0	0.00
Arkansas x Summer Rambo	103	1	.97
Arkansas x Jonathan	181	0*	0.0*
Arkansas x Selfed	150	0	0.00
Set of Fruit on Tree II			
Arkansas x Delicious	163	36	32.1
Arkansas x Northwestern Greening	79	17	21.5
Arkansas x Open Pollinated	1005**	186**	18.5

*Pollen proved to be non-viable in germination tests. This was unusual and cannot be explained. Results secured cannot be given much value.

**Bees and blossoming branches of Jonathan placed near tree.

In this orchard, Arkansas set well with Red June, Delicious and Northwestern Greening pollen. Grimes and Summer Rambo gave

practically no set. Open pollinated set from pollen of Jonathan branches which were placed near bee hives in the orchard was satisfactory.

Orchard Near Westminister: In this orchard, the trees were about 25 years old and growing in sod. Jonathan trees were interplanted.

TABLE III—SET OF FRUIT ON ARKANSAS

Variety cross	Number of blossoms crossed	Number of blossoms set	Per cent of blossoms set
Arkansas x Delicious	192	25	13.0
Arkansas x Yellow Transparent	146	30	20.5
Arkansas x Red June	151	54	35.7
Arkansas x Jonathan	199	5*	2.5*
Arkansas x Grimes	100	0	0.0
Arkansas x Selfed	150	0	0.0
Arkansas x Open Pollinated	150	30	20.0

*The pollen used germinated poorly in sugar solution, so results are questionable. Ordinarily Jonathan pollen germinates well.

In this orchard, Delicious, Yellow Transparent, and Red June pollen caused satisfactory sets. Grimes was again a failure. Jonathan pollen used was not very viable so too much weight cannot be

TABLE IV—SET OF FRUIT ON ARKANSAS

Variety cross	Number of blossoms crossed	Number of blossoms set	Per cent of blossoms set
TREE I			
Arkansas x Delicious	285	18	6.3
Arkansas x Jonathan	473	0*	0.0
Arkansas x Grimes	114	0	0.0
Arkansas x Selfed	150	0	0.0
Arkansas x Open Pollinated	425	25	5.9
TREE II			
Arkansas x Delicious	80	8	10.0
Arkansas x Jonathan	47	3	6.4
Arkansas x Wealthy	120	1	0.8
Arkansas x Open Pollinated	144	24	16.6
TREES III AND IV			
Arkansas x Yellow Transparent	226	2	0.88
Arkansas x Hubbardston	246	9	3.6
Arkansas x Wealthy	100	0	0.0
Arkansas x Grimes	364	0	0.0
Arkansas x York Imperial	173	5	2.9
Arkansas x Summer Rambo	209	0	0.0
Arkansas x Gano	190	9	4.7
Arkansas x Golden Delicious	111	2	1.8
Arkansas x Selfed	150	0	0.0
Arkansas x Open Pollinated	912	46	5.04

*Pollen was not viable when tested in sugar solution. Delicious and Grimes pollen germinated well.

given to poor results. Open pollinated set with Jonathan was satisfactory.

Orchard Near Sandy Springs: This orchard consisted mainly of Arkansas and Stayman Winesap with a few Grimes trees at one end. Yields were generally poor unless weather was good at pollination time, when pollen was no doubt carried by bees from a nearby orchard of Yellow Transparent, Jonathan, Ben Davis and other varieties. Trees were about 15 years old, and the orchard was cultivated. Bees and blossoming branches of Delicious and Jonathan were placed in this orchard in 1925.

Where Delicious pollen was used on Trees I and II satisfactory sets occurred. Grimes pollen gave no sets on Trees I and III. Pollen of Hubbardston, York Imperial, Gano and Golden Delicious caused some fruit to set. Yellow Transparent and Wealthy were not satisfactory.

Results at College Orchard: The pollen of 3 varieties was used on an Arkansas tree at the College.

TABLE V—SET OF FRUIT ON ARKANSAS TREE

Variety cross	Number of blossoms crossed	Number of blossoms set	Per cent of blossoms set
Arkansas x Delicious	185	40	21.6
Arkansas x Stayman Winesap.	100	0	0.0
Arkansas x Grimes	139	8	5.7
Arkansas x Selfed	200	0	0.0
Arkansas x Open Pollinated	255	50	20.0

Delicious again caused as good a set as open-pollination. This was the only case of all the orchards where Grimes pollen caused a fair set during 2 seasons. Weather conditions at the College were unusually satisfactory for pollination and tree growth, and this may explain the result. It will be noticed that the open-pollinated "set" was much better than in 1924 at the College. Occasionally, under certain weather conditions, apparently favorable for Arkansas pollination and tree growth, fair crops of Arkansas are borne under field conditions This seems, from general observations, to have occurred about once in every 5 years.

GENERAL FIELD EXPERIMENTS

During the spring of 1925 arrangements were made to have several hives of bees placed in each of 2 different orchards in the state. These orchards consisted of Arkansas and Stayman Winesap trees, and had been shy bearers. Flowering branches of Delicious and Jonathan were placed in buckets of water directly in front of the bee-hives. These branches were replaced with fresh ones once during the blossoming period. In one orchard, which was blossoming well, a good commercial crop was produced. The other orchard blossomed rather lightly, but most of the blossoms "set." This checked up commercially the above results of controlled cross-pollination ex-

periments as to the value of Delicious and Jonathan pollen for causing a set on Arkansas?

Orchard Observations

In a general survey which was made of many of the orchards in the state, 3 were found which were producing good crops of Arkansas. Two of the orchardists stated that they had never had any trouble in securing good crops of Arkansas. In one case the Arkansas trees were interplanted with Delicious and Jonathan. In the other orchard Delicious was interplanted with the Arkansas. The third orchardist stated that Arkansas always bore good crops in one field and very poor crops in another. He was anxious to find out why this was so. An investigation revealed the fact that there was about one Jonathan tree for every 20 Arkansas trees in the orchard that bore good crops, while the other orchard had no Jonathan trees interplanted, but was located near an orchard of York Imperial.

Discussion

The results of the controlled cross-pollinations and the general field experiments and observations indicate strongly that one of the main reasons why the Arkansas has not set well in commercial orchards, is that suitable pollen probably was not available. The pollen from several varieties gave a good to fair set on Arkansas during the 2 years' tests as seen by the tables. In many orchards throughout the Shenandoah-Cumberland Valley region, Arkansas has often been interplanted with Grimes It is clear from the above evidence that Grimes pollen cannot be relied upon to give a set of fruit on Arkansas. Other orchards have often consisted of Arkansas and York Imperial. The preceding controlled crosses would indicate that fair crops should result from this cross, especially if the orchard was located in a section where the varieties blossomed nearly together, and if the York Imperial rows were close to those of Arkansas. At College Park the York Imperial blossoms too late in most years to be a satisfactory pollenizer for Arkansas. One orchard, presumably of Arkansas and York Imperial, which had been bearing good crops in a nearby state, was found to have an occasional Delicious tree interplanted, and a home garden orchard of several varieties not very far distant. In this case, probably much of the credit of the Arkansas crops must be given to the pollen from the Delicious and other varieties.

The authors do not happen to know of any case where Arkansas has been closely interplanted with Yellow Transparent, Wealthy, Hubbardston, Red June, and Northwestern Greening,—the other varieties in addition to Jonathan and Delicious, which caused from good to fair sets in the controlled crosses.

The evidence presented suggests that if Arkansas trees had been interplanted with Delicious or Jonathan during the past 20 years, favorable crops probably would have resulted, provided that good pruning, soil management and fertilizer practices had been used. Surely the evidence presented seems clear cut enough to recommend

that growers defer the removal or top working of their Arkansas orchards for another year at least. If similar results are found again next spring, we should feel safe in saying that the problem of "poor setting" in the Arkansas has been solved, and that this excellent commercial variety is saved for our fruit industry.

Cross-Incompatibility

The almost complete lack of "set" when Grimes pollen is placed on the stigmas of the Arkansas blossoms presents a case, under our conditions, of cross-incompatibility in apples. Poor sets between Arkansas and Stayman Winesap may be explained because of the fact that Stayman Winesap pollen does not seem to germinate satisfactorily, but the pollen of Grimes does germinate very well in sugar solutions even through a wide range of temperatures. The reason for this cross-incompatibility has not been determined. Anyone of several possible reasons which have been suggested in recent years by various investigations might explain the condition, or the cause might be entirely different from any of these.

General observations relative to the fruiting of the Arkansas over a period of 12 years indicate that occasionally, fairly good crops will occur in an orchard for one year, and then poor crops may result again for several years. Apparently all conditions both within and without the tree must be very satisfactory for a set of fruit, unless unusually compatible pollen is available.

Cases of cross-sterility in apples have been previously reported by Powell (3), Close (4), Auchter (1), Hooper (5), Gourley (6), Sax (7), and others. Hendrickson (8), has reported the plum varieties, Formosa x Gaviota, to be cross-incompatible. Gardner (9) found the Bing, Lambert and Napoleon sweet cherries to be cross-incompatible and similar conditions have been found by Tufts (9), and Tufts and Phillips (10), to exist with certain varieties of almonds. Apparently it is not sufficient in many cases to simply interplant any 2 varieties in the orchard. With certain varieties cross-incompatibility exists either entirely or in part. This suggests that thorough studies could well be made to determine the best pollenizers for our different varieties of fruit.

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Notes on the Dropping of Immature Sour Cherry Fruits*

By Miss DOROTHY BRADBURY, *University of Wisconsin, Madison, Wis.*

IT IS well known by those interested in the growing of orchard fruits that large numbers of pomaceous and stone fruits fall from the trees before developing to maturity. Sterility, unfavorable weather at the time of blossoming, lack of pollination, lack of fertilization, and competition for nutritive materials, are conditions to which this dropping is most frequently attributed. Since the literature pertaining to this problem contains almost no references to the sour cherry, it seems worth while to present briefly some of the results of observations made during the past 6 years of the dropping of sour cherry fruits. The principal varieties worked with were Early Richmond and Montmorency; and the material for study was obtained from orchards in Sturgeon Bay, Oshkosk, and Madison, Wisconsin.

The investigation was begun with the aim of determining whether dropping is primarily due to any or all of the following conditions: (1) sterility, in the usual sense of setting no fruit when self- or cross-pollinated; (2) lack of pollination; (3) failure of pollen tubes to reach the ovarian cavities; and (4) lack of fertilization. It was found that fruit was set in both varieties whether the flowers were self- or cross-pollinated. This indicates that Early Richmond and Montmorency varieties are self- and inter-fruitful, at least under Wisconsin conditions. Self-pollination gave a lower percentage set than cross-pollination. Further experiments are necessary to determine whether this difference is of constant occurrence.

In the sour cherry, as in pomaceous and stone fruits in general, the dropping of the immature fruits occurs in rather distinct waves which

*The work here reported was carried on under the supervision of Dr. R. H. Roberts, University of Wisconsin. The writer gratefully acknowledges his helpful advice and criticism.

TABLE I—RESULTS OF DISSECTION OF FIRST DROP AND DEVELOPING FRUITS

Class	Place of collection	Year of collection	Number	Location of pollen tubes: In ovarian cavities, Number	Location of pollen tubes: In ovarian cavities, Percentage	Location of pollen tubes: In styles only	Location of pollen tubes: Total percentage in cavities or styles	Fruits with endosperm or embryo	Total percentage with endosperm or embryo
Drop fruits	Sturgeon Bay and Oshkosh	1920 1921	112	86	76.7	6	82.1*	—	—
	Madison	1924	156	153	98.0	2	99.3	0	0.0
	Total	—	268	239	89.1	8	92.1	—	—
Developing fruits	Madison	1924	84	23	27.1	0	27.1	61†	72.5

*In 9.8 per cent, tubes were absent; in the remaining 8 per cent, presence of tubes was doubtful.
†Embryos were easily distinguished in 40 out of 61 fruits examined.

TABLE II—DROP FROM UNPOLLINATED AND CHECK (CHANCE POLLINATED) BRANCHES

Variety	Treatment	Total blossoms	Total drop in percentage of total blossoms	Percentage of total blossoms dropping in each wave: First drop	Second drop	Third drop
Montmorency	Emasculated unpollinated unbagged	727	98.9	46.3	52.4	0.1
	Check (chance pollinated)	2,036	65.2	33.7	27.2	4.3
Early Richmond	Emasculated unpollinated unbagged	715	99.9	63.0	36.8	0.1
	Check (chance pollinated)	1,412	69.4	42.0	24.7	2.7

have been commonly spoken of, and will also be referred to here, as the first drop, the second drop, and the third or "June" drop. The fruits which fall in these respective drops may be distinguished from those which remain on the tree until the subsequent drop, or until maturity, several days before they are completely abscised. For an examination of conditions within the pistils, it is important to obtain these aborting fruits before marked degeneration has followed upon their arrested development. Consequently, collections were made of aborting fruits of the first, the second, and the third drop as soon as they could be distinguished with certainty. In the present discussion, then, first-drop, second-drop, and third-drop fruits refer to aborting fruits whose appearance was taken as evidence that they would fall in these respective drops.

Drop fruits were examined for the presence of pollen tubes and embryos to determine whether pollination and fertilization had taken place. Free hand razor sections of fixed material were dissected in a solution of resorcin blue which stains the callose present in the walls and plugs of pollen tubes. The conditions observed in the free hand sections of the fruits were verified from stained microtome sections of material imbedded in paraffin.

From the results of the present study, the first drop, considered as a whole, cannot be attributed to lack of pollination or to failure of pollen tubes to reach the ovarian cavities. Table I shows that from 82 to 99 per cent of the first drop fruits examined had been pollinated and that, in 76 to 98 per cent, pollen tubes had reached the ovarian cavities. The lower percentage of pollination at Sturgeon Bay and Oshkosh is apparently the result of less bee visitation of blossoms in those locations. It has been noted that pollen carrying insects rarely visit the cherry blossoms in orchards at Sturgeon Bay (3).

It is probable that degeneration begins in the ovules of fruits which fall in the first drop before the normal time for fertilization to occur. Although 2 ovules are formed in the ovary of a cherry pistil, one of them ordinarily aborts soon after full blossom time. When the aborting first drop fruits could first be distinguished, the developing fruits, with very few exceptions, contained one shriveled aborted ovule and one large turgid ovule. Embryos of 2 to 4 cells were present in many of the large ovules. On the other hand, in over four-fifths of the aborting first drop fruits *both* ovules were shriveled. There was no evidence that the rate of pollen tube growth had been appreciably slower in the aborting fruits. The marked shriveling of both ovules and the apparently random growth of the pollen tubes in the upper portion of the ovarian cavities of these fruits, indicated that degeneration in the ovules was already well advanced by the time the pollen tubes entered the cavities.

The practical independence of the first drop from the question of pollination is further illustrated by a comparison of the drop in 1925 from unpollinated and check (chance pollinated) branches. It is evident from Table II that unpollinated fruits are abscised at the time of the first or second drop. (The small percentage setting is attribu-

table to chance pollination.) It was found that ordinarily 93 to 97 per cent of the blossoms on check branches are pollinated. Table II shows that, on a percentage basis, the first drop from unpollinated branches consisted of one-third to one-half more fruits than the first drop from check branches. Lack of pollination apparently prevented some fruits from developing beyond the first drop. But the large percentage of *pollinated* fruits which *were* abscised at the time of the first drop and the large percentage of *unpollinated* fruits which were *not* abscised at this time indicate that the mere fact of pollination or of lack of pollination does not fully account for the development of fruits beyond the first drop nor for their abscission at that time.

The second drop, like the first drop, cannot be attributed primarily to lack of pollination or to failure of pollen tubes to reach the ovarian cavities. Table III shows that a large part of the second drop is not due to lack of fertilization since embryos were present in 41 per cent of the sectioned second drop fruits and no indications of apogamy were observed. Out of a limited number (72) of these fruits, 95 per cent either contained embryos or had pollen tubes in the ovarian cavities or in the ovules.

TABLE III—RESULTS OF DISSECTION OF SECOND-DROP AND DEVELOPING FRUITS

	Number		Percentage	
	Drop fruits	Developing fruits	Drop fruits	Developing fruits
Embryo present	107*	72	41.1	96.0
Embryo sac degenerate or stage of development previous to embryo or endosperm formation	153	3	58.8	4.0
Total	260	75	99.9	100.0

*Sixty-nine of these fruits contained a degenerate embryo or degenerate endosperm.

The embryo sac contents of a large number of the aborting fruits of the second drop were completely disorganized. It is an open question whether this condition was due to lack of fertilization, or whether it had begun to develop early enough to preclude the possibility of fertilization.

Fertilization and a partial development of the embryo has usually taken place in aborting third drop fruits of the sour cherry. A similar condition has been reported for the plum by Dorsey (2) and for several orchard fruits by Detjen (1). Of 250 third drop cherry fruits, all but 2 contained embryos or endosperm tissue and 94 per cent contained embryos.

The data presented thus far indicate that in Wisconsin the dropping of Early Richmond and Montmorency sour cherry varieties is not primarily the result of self- or cross-sterility as expressed in failure to mature fruits, of lack of pollination, or of failure of pollen tubes to reach the ovarian cavities, and also that much of the later dropping is

certainly not caused by lack of fertilization. Since none of these conditions seems to be the major cause of the abscision of the immature fruits, the influence of nutrition upon their abscision should receive careful consideration. The following observations suggest that nutritional conditions greatly affect the amount of fruit dropping.

When there is an unusually light production of blossoms due to excessive winter killing of the over-wintering blossom buds and individual blossoms, the percentage of blossoms which set fruit is ordinarily larger than in other years. A record of the distribution of the total drop in 4 different years shows that the later drops tend to be less if the early drops are heavy, and greater if the early drops are light. In 1924, blossom buds on spurs of two-year-old wood were thinned as early as practicable to 1 blossom to a bud. The set was increased from 24 per cent on unthinned branches to 42 per cent on thinned branches. In the same year a record was made at harvest time of the pit diameter and seed condition in large fruits from vigorous branches and small fruits from weak branches. The small fruits contained smaller pits and a larger percentage of shrunken seeds than the large fruits. Roberts (3) has shown that methods of pruning and fertilizing which bring about a greater growth of trees than is commonly found in commercial orchards result in an increased set of fruit.

These observations, coupled with the early ovule degeneration in the first drôp fruits and frequent embryo abortion in the later drops, make it appear probable that unfavorable nutritional conditions play a major part in bringing about the arrested development and dropping of the immature sour cherry fruits. In this event, a study and comparison of the kind and rate of histological and physiological changes occurring in the developing and aborting fruits, especially in the abscision region, would aid in determining the way in which nutritional conditions in the cluster base, spur, or branch, affect the set of fruit. It should be kept in mind that the stage of development reached by an individual fruit is influenced not only by foods and food materials received through the pedicel but also by stimuli acting upon the carpel or ovule, such as pollination, fertilization, or embryo development. It is possible that the physiological conditions in the fruits leading to the formation of an abscision layer are the same whether they have been brought about by unfavorable nutritional conditions or by the lack of pollination or fertilization. If such is the case, a study of the conditions within unpollinated fruits, which in the cherry almost invariably drop, and within pollinated fruits that are favorably situated for development to maturity, might afford a comparatively easy and profitable starting place for an investigation of the physiological and histological factors immediately responsible for fruit dropping resulting from nutritional conditions. It is planned to continue the study of the drop question along the lines just suggested.

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The Relation of Temperature to Pollen Tube Growth in Vitro*

By H. E. Knowlton and H. P. Sevy, *University of West Virginia, Morgantown, W. Va.*

WEATHER at the blooming period is one of the most important factors affecting the setting of fruit. Winds may seriously delay or entirely prevent proper cross pollination if bee flight is retarded. Prolonged rains may delay anther dehiscence as well as prevent bee flight. An unfavorable temperature may, according to Dorsey (1919), influence setting of fruit in three ways: "(1) its direct effect upon pollen or pistil, (2) its influence upon pollen tube growth, and (3) its interference with bee flight." However, the ultimate result is the same irrespective of what element of the weather is concerned, i. e., fertilization does not take place. Pollination may occur but too late. The pollenizer may produce pollen that grows slowly. Temperatures may be low or unusually high resulting in slow pollen tube growth As a result embryo abortion may occur before the tube reaches the ovules and the flower will fall.

The relation of temperature to pollen tube growth has not been extensively investigated, although most investigators have realized its importance in fruit setting. Due to difficult technique none of this work has been done within the pistil itself, but in artificial sugar solution cultures. Goff (1901) found that pollen of Moldavka and Wood plums, Dyehouse cherry and Prunus apple germinated very poorly at 40°F. Growth was best at 65°–70°F. Pollen of Vermont Beauty pear and an unknown variety of strawberry did not germinate at 40°F. He concluded that with the cherry and plum, pollen tube growth is not appreciably retarded until the temperature goes below 51°F. Sandsten (1909) concluded that the optimum temperature for apple, pear and plum pollen tube growth in sugar solutions is 75°F., while Adams (1916) found the quickest germination of apple pollen at 80° to 85°F. Some apple pollen germinated at 38° to 45°F. Manaresi (1912), however, concluded that 59°F. was the most favorable temperature. Martin and Yocum (1918) found that their best growth

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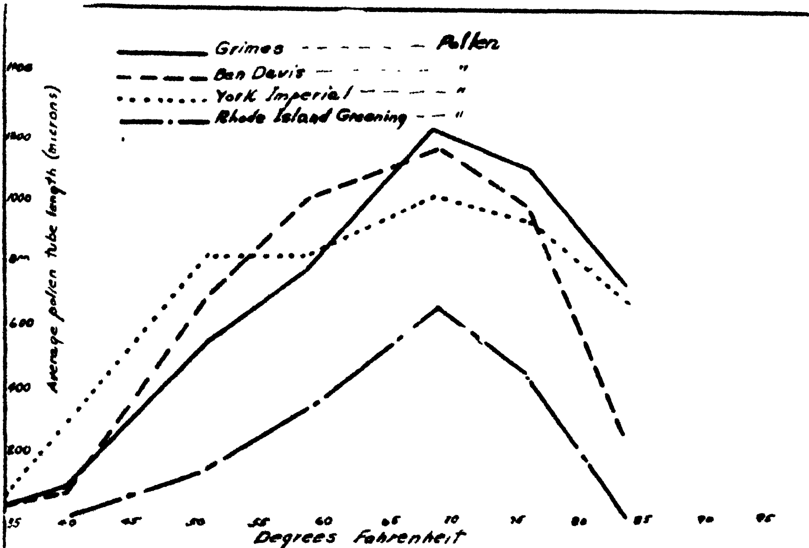
with apple pollen was at 72–77°F. They also reported 5 per cent germination at 29°F. Beaumont and Knight (1922) carried on pollen germination tests at 60°–70°F., while Auchter (1921) in many of his experiments used 85°F. This wide difference in results might be explained by the fact that different conditions probably existed. The time factor was not the same for all workers. Some probably determined it by percentage of germination while others by maximum growth.

That there are wide differences between species is shown by the fact that the author (1922) found that the optimum for snapdragon pollen germination is 77°F., while Sutton and Wilcox (1912) found the optimum for tomato pollen germination to be 93°F. Popenoe (1917) reported that the optimum temperature for mango pollen germination is 77°F. with no germination below 61°F.

East and Park (1918) with Nicotiana found that pollen tube growth proceeded at an accelerated rate as the tube neared the ovary. In vitro, pollen tube growth proceeded at a greatly reduced rate as the time increased.



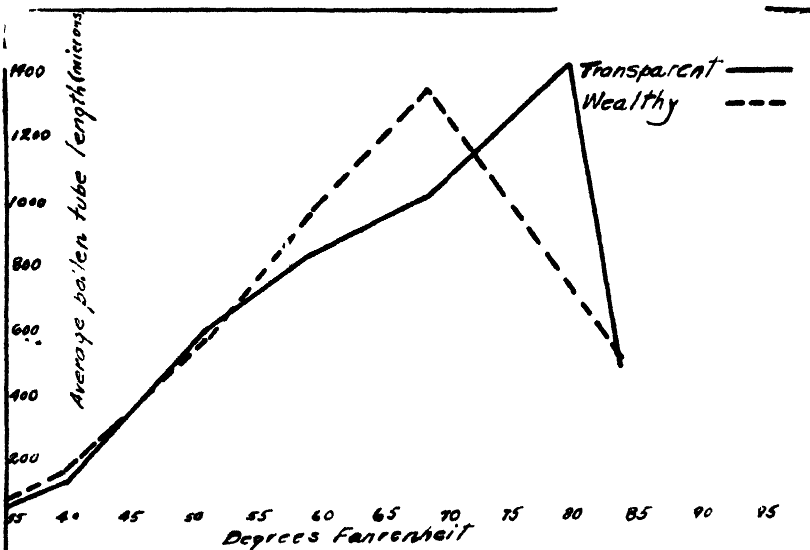
EFFECT OF TEMPERATURE ON LENGTH OF GROWTH OF POLLEN TUBES 1924

FIGURE I

If trustworthy results applicable to orchard conditions are to be obtained on the effect of temperature on pollen tube growth the studies should be made in the style of the growing plant. Technical and practical difficulties of experimentation make this mode of approach almost impossible. The authors have, therefore, tried in this study to make conditions as nearly uniform as possible, varying only the temperature.

Experimental Methods

Methods of germination did not differ materially from those of other workers. The germinating medium was a 10 per cent solution of cane sugar to which one gram of agar had been added to each 100 cubic centimeters of solution. Enough of this medium to make thin films was poured while hot into small Petri dishes (about an inch in diameter). Before the pollen grains were spread upon its surface the medium was brought to the temperature at which germination was to be tested. The following temperatures were used in each variety series in 1924, 32°–34°, 38°–42°, 51°, 59°, 69°, 76°, and 83°–85° Fahrenheit, and in 1925, 42°, 54°, 65°, 77°, 86°, and 97° Fahrenheit. Pollen was taken from one anther in each series of tests. From 50 to 100 pollen grains were carefully distributed on the hardened medium, the



EFFECT OF TEMPERATURE ON LENGTH OF GROWTH OF POLLEN TUBES 1924

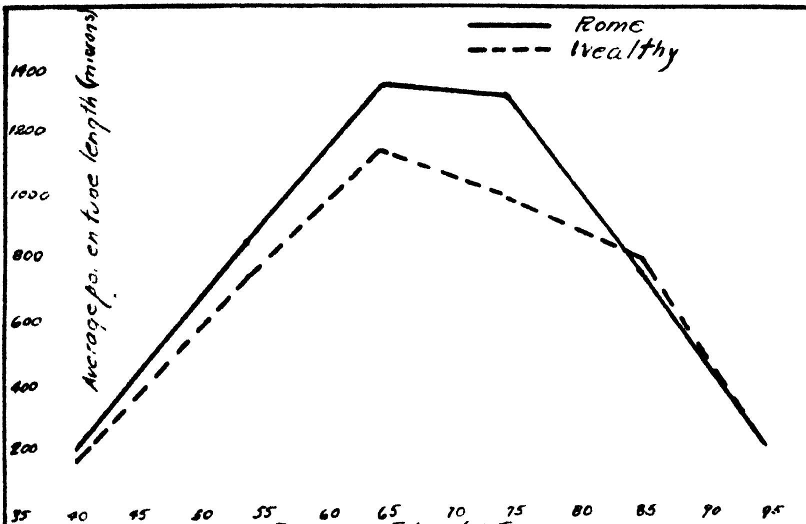
FIGURE 2

operation being performed under a binocular microscope. Growth measurements were facilitated by having the pollen grains well separated from each other. The Petri dish was always taken directly to the oven of the temperature to be tested. At the 24 hour interval the culture was removed and the lengths of at least 10 tubes measured with the ocular micrometer. The average of these for each temperature is the value given in Figures 1 to 3. No data on percentage of germination are given because no differences were noticeable except at the low temperatures.

Results

Figures 1 to 3 present the data obtained in 1924 and 1925 in the form of curves for each variety series. At least 3 series were run for each variety, the ones presented being typical. It will be seen that no germination occurs at or below freezing, that the greatest growth rate is between 65°–70°F., and that a pronounced depression in growth occurs above 75°F. At these higher temperatures tube growth is granular in appearance, and bursting of the pollen tube tips is common.

It is also seen that all varieties present similar growth curves. Rate of growth for Rhode Island Greening pollen was much slower than for any of the other varieties. Rates of growth for pollen of



EFFECT OF TEMPERATURE ON LENGTH OF GROWTH OF POLLENTUBES 1925
FIGURE 3

Rome Beauty, Wealthy, Grimes, Ben Davis, York Imperial, and Yellow Transparent were approximately the same. Stayman Winesap and Arkansas (Black Twig) pollen germinated so poorly that no typical growth curves could be obtained.

In a number of instances cultures which had been incubated at the lower temperatures with little or no growth were removed to a higher temperature for 48 hours. In every instance germination occurred and growth was continued at the normal rate for the higher temperature.

Some cultures were also taken from the 84° oven and placed in an oven at 68°. No recovery occurred. Apparently the high temperature had permanently injured the growing grains.

Discussion

The authors are cognizant of the fact that the application of the above data to the problem of fruit setting in the orchard is attended with considerable danger. It is believed, however, that pollen germination and initial tube elongation on an artificial medium are normal. East and Park (1918) have said "there seems to be no question but that there is a true germination and a real growth on artificial media." After a certain length of time, however, growth becomes slower. This was shown by growth-temperature curves plotted for the same cultures after 48 hour incubations. Without exception they were much flatter than those plotted after 24 hours, showing that the longer tubes were growing at a reduced rate. It is possible that growth temperature curves plotted after a shorter interval than 24 hours would show sharper curves than those presented in Figures 1 to 3.

The authors feel that the results suggest the following applications to fruit-setting:

1. Since temperature affects in a similar way the growth rate of pollen of the varieties studied, it would probably affect them similarly in the orchard whether they were growing in "selfed" or in "crossed" pistils. Roberts (1925) has found that for pollen tubes in self-pollinated blossoms, the rate of growth was as rapid as in cross-pollinated flowers. In other words, all varieties should have about the same optimum temperature for fruit setting if rate of pollen tube growth is the only factor considered.

2. As pollen tubes are not injured by temperatures above freezing (35°-40°F.) for limited periods (48 hours), it would seem that the only effect of short spells of cool weather at bloom would be that pollen tube growth is slower with a consequent delay in fertilization. This is postulated on the assumption that low temperatures may delay embryo abortion for a short time, but not indefinitely.

3. When temperatures are *constantly* below 50°F. at pollination time, the set of fruit may be considerably decreased because of slow pollen tube growth, the embryo aborting before the pollen tube reaches it.

4. Abnormally high temperatures at bloom (75°–85°F.) may reduce the set by its permanently injurious effect on pollen tubes and pollen tube growth. Such warm weather occasionally occurs in West Virginia at blossoming time. It is probable, however, that with an air temperature of 85°F. the temperature within the pistil would be 1 or 2 degrees lower. Since under orchard conditions high temperatures do not ordinarily continue longer than a few hours, it is questionable whether any injury would occur. In these studies no observations were made at shorter periods than 24 hours.

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Some Observations on the Effect of Inbreeding on the Vigor of Apple Seedlings

By H. L. Lantz, *Iowa State College, Ames, Iowa*

APPLE Breeding has been one of the major projects for investigation since the organization of the Department of Horticulture at Iowa State College. The apple breeding work has gone through many stages during these years; first, the planting of selected seeds, then the crossing of selected parents and, finally, inbreeding.

This work has engaged the major portion of the author's attention for the past 9 years. During this time thousands of cross-bred apple seedlings have been produced from many lines of breeding and combinations of varieties. Considerable attention has been given the matter of inbreeding cross-bred seedlings of known parentage. It has been hoped that by recombining those seedlings showing desirable phenotypic character, that valuable information on the manner of inheritance of some of the factors for vigor of tree, size, color, quality and season of fruit might be secured.

Selfing of the apple has been extremely difficult and, when accomplished, has produced seeds of fair to poor germination and the trees are often low in vitality and vigor. Naturally, therefore, the major

portion of the apple breeding work has consisted of crossing varieties for the purpose of studying inheritance, and to originate new and better varieties suited to peculiar conditions. The complex hybrid nature of the apple varieties is reflected in the progeny produced. This complexity permits little of genetic fact to be discovered, but the progeny thus developed is the foundation material which the apple breeder has at hand. Trees of known parentage mark a step in advance in that we now have material of which we know the immediate parentage with which to affect new combinations by back crossing, sib crossing and out crossing. We may not be able to predict what the resulting seedlings may be like, but it is possible to bring together seedlings of desirable phenotypic characteristics with the idea of intensifying these characteristics in the right horticultural direction. Whether inbreeding of the apple is to give results, either in determining the method of inheritance, or in the production of new and improved horticultural varieties, is still a matter for investigation.

The cross bred progeny of many combinations of parents which have been made has yielded considerable valuable information in regard to the desirability or prepotence of the varieties used, and clearly indicates that certain varieties are valuable in transmitting to their progeny desirable horticultural characteristics. The published work of Macoun, Hedrick and Wellington, Auchter, Lantz and other workers has brought together considerable information as to prepotence in apple varieties.

Inbreeding to develop pure lines has been urged as the most likely method of securing new improved varieties. Jones urged this method before this society in 1915, and in his recent textbook he sees little hope of improvement in the apple until pure lines are established.

By using material of known parentage for inbreeding in various ways, sib crosses, back crosses, etc., the geneticist tells us we are to begin to purify the lines of breeding. It is unfortunate that self-breeding is as difficult as it is with the apple. The next avenue open is to make sib and back crosses. Jones states, "On the average 6 generations of self-fertilization are more effective than 17 generations of brother and sister matings in bringing about uniformity." Since it requires from 8 to 12 years or more to bring a single generation of apples into fruiting, the problem of purifying the line looms up as one requiring the combined efforts of several generations of workers. For the present, we are prone to believe that new valuable varieties will be developed by a scientific system of out crossing, where varieties of proved performance shall be brought together and seedlings produced in large numbers. We are reminded that nature, unassisted, has produced many notable new varieties, some within the memory of most of the members of this society. These varieties, doubtless, are an extreme plus variation in the right horticultural direction. Here lies our hope of securing further improvements as more and more is learned about the prepotence of the varieties at the disposal of the apple breeder.

Numerous investigations on the self-fertility of the apple have been made. Gowen in a series of tests (Maine Bul. 287) found 42 varieties out of 119 tested which were self-fertile, in so far as fruit set, but there is no information given as to the viability of self-fertilized apple seeds. Crandall observed that certain varieties may be self-fertile 1 year and sterile the next. On 148 forms of Malus involving 22,619 pollinations, he succeeded in securing 1486 fruits or 6½ per cent. A total of 2840 selfed seeds produced 703 trees, 219 of which are living. Recognizing the genetic value of inbred material, Crandall concludes that the work of self-fertilizing is worth the effort even though the results secured are comparatively small.

Hedrick and Wellington reported 3000 selfed grape seedlings to be "uniformly lacking in vigor." Wellington reports that 27 trees of Baldwin selfed were planted in 1909 and that all but one died, presumably because of weakness due to a combination of non-vigorous gametes. In commenting on the general vigor of inbred apple trees he also states, "F_2 progeny where Ben Davis occurred as one parent, the rows of self-fertilized seedlings could be readily distinguished from the F_1 generation cross fertilized seedlings by their smaller size." East and Hayes and Jones working with corn show that in breeding there is a reduction in vigor which proceeds for about 9 generations. Normal or even superior vigor was restored by crossing.

Hybrid vigor has been noted in many kinds of plants and animals, and is known as heterosis. The dominance hypothesis advanced by Jones is doubtless the best explanation for heterosis we have today. There is little reason to believe that an analagous situation does not exist in apples with respect to vigor factors, namely, that the factors controlling vigor are multiple in nature

In the apple breeding work at the Iowa Station, self-breeding has been practically without result. As fruit breeding material of known parentage became available, sib and back crosses have been made with little more difficulty than is encountered in making out crosses. The resulting seedlings have in the aggregate shown a lack of vigor as compared with seedlings of out crosses. This lack of vigor and good habit have been very pronounced, and a large percentage of the trees has not been worthy of a place in the trial orchard. The data herewith presented have been helpful to us in formulating plans for further breeding and we present it in this paper hoping that such data may be of value to others engaged in the breeding of better apples.

Out of the work initiated by Beach, two lines of breeding have developed which are of extreme interest. These are the Salome x Jonathan and the McIntosh x Longfield. The Salome x Jonathan cross has produced a goodly percentage of late keeping, red apples of good to very good quality. There seems to be partial dominance for a lack of vigor in the trees. McIntosh x Longfield has been prepotent in transmitting good healthy trees, with many fruits of excellent size, color and quality, but of fall to mid-winter season. These two lines present phenotypes both in tree and fruit which encourage their use for inbreeding and also for further outbreeding studies.

In 1923, viable seeds were secured from 11 sib and 3 back crosses of McIntosh x Longfield F_1 trees. Only 1 sib cross of Salome x Jonathan F_1 was secured, while 6 back crosses produced viable seeds. Jonathan selfed produced 59 seeds, only 2 of which germinated. Both are small, weak trees.

Seedlings of the Salome x Jonathan outcrossed with seedlings of McIntosh x Longfield produced viable seeds in 3 cases. This type of cross was made to compare vigor thus produced with that produced by sib and back crosses of the same lines of breeding. Seeds from 10 combinations by using pollen of McIntosh x Longfield (F_1) seedlings on standard varieties and on seedlings of known hardiness, were secured. Four similar combinations were made by using pollen of 1 of the Salome x Jonathan seedlings.

The number of seedlings grown in many cases is disappointingly small, due to poor germination of the seeds. This was particularly true in the sib crosses of McIntosh x Longfield. Even though the number of trees is small, there is an evident lack of good habit and character of tree that stands out to one who has watched the general progress of apple seedlings for a number of years.

The data presented in the accompanying table were obtained in September of 1925. The seeds were produced in 1923 and germinated in seed beds out of doors in the spring of 1924. The trees were measured for height to the nearest inch and calipered to sixteenths of an inch. In this discussion, growth as expressed in height of tree is taken as criterion for potential or inherited vigor.

What is the effect of inbreeding upon the viability of the seeds? From 11 sib crosses of McIntosh x Longfield, 308 seeds were secured. Eighty-four or 27.2 per cent germinated. In 3 back cross combinations with McIntosh the mother parent, 35 seeds were secured, 27 or 77 per cent of them germinated. McIntosh outcrossed in 3 combinations produced 51 seeds, 27 or 53 per cent germinated. The indications are that sib crosses of the McIntosh x Longfield line of seedlings produce seeds lacking in good viability. Great irregularity in viability of sib crossed seed is noted, ranging from 1.3 per cent to 45 per cent germination in different lots.

In the Salome x Jonathan line of breeding, only 1 sib cross was secured, Ames 494 x Edgewood. One hundred and seventy-eight seeds were secured, 97 or 54 per cent germinated, which is higher than was secured from any of the McIntosh x Longfield sib crosses. Five back crosses with Jonathan the pollen parent, produced 408 seeds, 156 or 38.2 per cent germinated. One back cross with Jonathan the seed parent produced 49 seeds; 41 or 84 per cent germinated. The germination of back crossed seed was irregular but generally higher than in the McIntosh x Longfield line, varying from 16 per cent to 84 per cent. Out crosses between individuals of these two lines (McIntosh x Longfield) x (Salome x Jonathan) were made for reasons before explained. Four combinations produced 259 seeds, 154 or 59.5 per cent germinated. This is a better showing than was made by the sib crosses of either line of breeding. There seems little doubt

that inbreeding in these two lines pulls the percentage germination downward. Sib combinations can be expected occasionally to produce seeds of high viability. Likewise, certain back cross combinations may be secured which may produce highly viable seeds.

What is the effect of inbreeding on the vigor and habit of inbred seedlings? There is often a marked difference between the seedling lots of the different lines of breeding. These differences are apparent at the end of the first year's growth, but show up quite distinctly at the end of 2 years.

The progeny produced by the McIntosh x Longfield line are superior in vigor to progeny of the Salome x Jonathan line. The difference in vigor is decidedly noticeable in the seed beds and the case is also proved statistically. This might be expected since the trees of F_1 generation of McIntosh x Longfield are generally more vigorous than are the trees of the F_1 generation of Salome x Jonathan.

The mean height of trees in the sib combinations of McIntosh x Longfield ranged between 30 and 45 inches. While this is a good showing as compared with out crosses of the same age, the fact remains that comparatively few trees in any of the lots are of good habit, but instead, often present a sprawling, open and scraggly type of growth. Past years experience with F_2 material leads to the conclusion that very few of these trees will make the grade and be good enough for a place in the trial orchard

A comparison of the sib with the back crosses of McIntosh x Longfield is extremely interesting. For example, 18 trees, progeny of Maud (McIntosh x Longfield) x Ames 492 (McIntosh x Longfield) have a mean heighth of 36.3 ±1 inches, and a coefficient of variability of 17.6 per cent. These trees rated good for vigor, 86 per cent of the trees being over 30 inches in height. Both Maud and Ames 492 were back crossed on McIntosh. McIntosh x Ames 492 produced 14 trees with a mean height of 17.4 ±1.7 inches and a coefficient of variability of 53.5 per cent. McIntosh x Maud produced 8 trees having a mean height of 18.5 ±1.3 inches and coefficient of variability of 30.9 per cent. In both back crosses, the mean height was scarcely more than half that of the sib crosses.

Back crossing in the case of the McIntosh x Longfield line reduced the vigor of the progeny very markedly, and at the same time, the coefficient of variability was nearly twice as large in 1 case and 3 times as large in the other as that of the sib crosses. Maud in 8 sib crosses produced seedlings with a mean height averaging around 30 to 36 inches. One lot of 3 trees, Ames 492 x Maud, averaged 45 ±2.0 inches and one lot of 12 trees, Ames 415 x Maud, dropped to 27.6 ±2.0 inches. It is not likely that Ames 492 x Maud would repeat with progeny with a mean so large if the numbers were larger. In the out cross of Wealthy x Maud, 5 trees were grown which showed a mean height of 38.6 ±1.2 inches. Patten 1035 x Maud produced 5 trees having a mean of 44.2 ±1.3 inches. The advantage in vigor lies with the out cross in most cases.

The results secured by inbreeding Salome x Jonathan progeny are more reliable than were secured with the McIntosh x Longfield line

APPLE BREEDING—TWO YEAR OLD SEEDLINGS. SEEDS PLANTED APRIL, 1924. DATA TAKEN SEPTEMBER 22, 1925

Parentage	Number seeds planted	Number seeds germinated	Per cent germinated	Number trees measured	Mean height	Standard deviation	Coefficient variation	Per cent trees 30 inches and under	Per cent trees over 30 inches
Sib crosses McIntosh x Longfield line.									
Maud x Ames 482	17	4	24	4	31.5±2.7	8.2	26.0	50.0	50.0
Maud x Ames 491	20	9	45	9	31.2±3.37	15.14	48.4	55.5	44.5
Maud x Ames 492	50	18	36	18	36.3±1.0	6.32	17.6	14.0	86.0
Maud x Ames 436	29	3	1.3	3	38.6±1.6	4.12	10.7	0.0	100.0
Ames 415 x Maud	21	12	41	12	27.6±2.0	9.7	35.1	66.0	34.0
Ames 492 x Maud	25	3	12	3	45.0±2.0	5.3	11.8	0.0	100.0
Ames 493 x Maud	20	8	40	7	30.9±1.4	5.66	18.3	44.0	56.0
Ames 497 x Maud	60	5	8	3	35.3±2.3	5.9	16.7	33.3	66.6
Ames 415 x Ames 492	33	10	30	9	31.2±2.2	9.64	30.8	55.5	44.5
Ames 415 x Ames 491	28	10	37	10	30.7±2.1	10.0	32.5	50.0	50.0
Maud x Ames 415	5	2	40	1	22.0	—	—	—	—
Back crosses McIntosh x Longfield line.									
McIntosh x Ames 492	21	16	76	14	17.4±1.7	9.1	52.3	92.5	7.5
McIntosh x Maud	10	9	90	8	18.5±1.3	5.56	30.0	100.0	0.0
McIntosh x Ames 482	4	2	50	2	24.0	—	—		—
Sib crosses Salome x Jonathan line.									
Ames 494 x Edgewood	178	97	54	87	20.5±0.6	8.6	42.0	83.0	17.0
Back crosses Salome x Jonathan line.									
Jonathan x Edgewood	49	41	84	38	23.0±1.0	9.9	43.0	81.5	18.5
Edgewood x Jonathan	72	51	71	49	25.8±0.73	8.6	33.3	74.0	26.0
Secor x Jonathan	22	15	68	13	19.0±1.4	7.7	40.5	93.0	7.0
Ames 496 x Jonathan	121	41	34	36	24.6±0.9	8.9	36.2	59.0	31.0
Ames 499 x Jonathan	112	36	32	25	31.4±1.0	7.5	24.4	42.0	58.0
Ames 498 x Jonathan	81	13	16	10	27.5±1.9	8.6	31.3	55.0	45.0
Jonathan Selfed	59	2	3.4	2	19.5	—	—	—	—

Parentage	Number seeds planted	Number seeds germinated	Per cent germinated	Number trees measured	Mean height	Standard deviation	Coefficient variation	Per cent trees 30 inches and under	Per cent trees over 30 inches
Out crosses (McIntosh x Longfield) x (Salome x Jonathan) line.									
Secor x Ames 491	149	95	64	94	25.2±0.5	8.2	32.8	72.4	27.6
Edgewood x Ames 415	81	46	57	41	33.4±0.7	6.7	20.0	36.0	64.0
Ames 495 x Ames 415	16	7	44	6	39.1±1.3	4.9	12.5	0.0	100.0
McIntosh x Edgewood	13	6	46	3	32.6±2.8	7.1	21.5	33.3	66.6
Out crosses F_1 progeny Salome x Jonathan.									
Edgewood x Delicious	62	28	45	24	32.9±1.6	11.8	35.9	50.0	50.0
Patten 1000 x Edgewood	82	27	33	26	34.4±1.03	7.8	22.7	34.5	65.5
King David x Edgewood	33	21	64	18	29.0±1.4	8.8	30.34	56.0	44.0
Patten 1015 x Edgewood	13	13	100	12	19.3±2.2	11.4	59.0	83.3	16.7
Out Crosses F_1 progeny McIntosh x Longfield.									
Brilliant x Ames 415	28	10	36	10	42.4±2.0	9.3	22.0	10.0	90.0
Wealthy x Maud	12	5	42	5	38.6±1.2	4.1	10.6	0.0	100.0
Patten 1035 x Ames 415	39	12	30	12	26.0±1.6	8.5	32.7	66.6	33.3
Patten 1035 x Maud	40	6	15	5	44.2±1.3	4.3	9.7	0.0	100.0
Wealthy x Ames 482	29	12	41	12	29.9±1.6	8.5	28.4	50.0	50.0
Fameuse x Ames 482	46	20	43	18	35.1±0.8	5.7	16.3	27.8	72.2
Out crosses.									
McIntosh x Fameuse	25	11	44	10	36.1±2.2	10.67	29.6	30.0	70.0
McIntosh x Delicious	12	10	77	9	32.2±2.2	9.8	30.5	55.5	44.5
Jonathan x Delicious	723	316	43.8	301	35.0±0.3	7.5	21.4	27.7	72.3
Delicious x Jonathan	130	64	44.2	64	38.0±0.5	5.8	15.3	14.0	86.0
Fameuse x Delicious	242	88	36	83	34.1±0.5	7.3	21.4	26.5	73 5

because the number of trees is sufficiently large to give more confidence in the figures.

Trees of 6 back crosses of Jonathan were secured. Jonathan was the male parent in 5 cases Unfortunately, only one sib cross was successful. Progeny of the back crosses ranged from 19 inches to 30.5 inches in mean height. Six out crosses involving Jonathan as 1 parent ranged in mean height of from 28 inches to 38 inches.

The sib cross, Ames 494 x Edgewood (Salome x Jonathan) produced 87 trees, with a mean height of 20.37 ±.62, standard deviation of 8.6, and coefficient of variation of 43.0 per cent. Edgewood used in 6 out crosses produced progeny in 5 cases with a mean height of 29 to 33 inches, which is a difference of 9 to 13 inches in favor of the out cross. In one Edgewood out cross (Patten 1015 x Edgewood), the mean dropped to 19.3 ±2.2 inches.

It is interesting to note the vigor responses where Salome x Jonathan (F_1) seedlings were crossed with McIntosh x Longfield (F_1) seedlings, and to compare the progeny with the progeny of the sib and back crosses. The out cross of Secor (Salome x Jonathan) x Ames 491 (McIntosh x Longfield) produced 94 trees with mean height of 25.2 ±.7. Secor x Jonathan (back cross), 13 trees were 19 ±1.4 inches mean height, a difference of 6 inches in favor of the out cross. Ames 491 entered into 2 sib crosses 1 with 9 trees and the other with 10 trees, with mean heights of 31.2 ±3.37 and 30.7 ±2.1 inches, which in both instances, is about 5 inches above the mean of the out cross of Secor x Ames 491. Secor evidently does not bring into the combination any factors for good vigor.

Edgewood (Salome x Jonathan) x Ames 415 (McIntosh x Longfield) produced 41 trees with a mean height of 33.4 ±.7 which is a better showing than was made by any progeny produced by either parent when involved in a sib or back cross. Again Ames 495 (Salome x Jonathan) x Ames 415, produced 6 trees with a mean height of 39.1 ±1.35 inches. This is a remarkably good growth for 2 years and is a decided advantage over any lot of trees produced by Ames 415 in any of the 4 sib combinations in which it was one parent.

It is regrettable that there is neither F_1 progeny of Salome x Jonathan, nor of McIntosh x Longfield F_1, with which to compare the sib and back crossed progeny of these lines of breeding. However, the visible evidence of the effects of inbreeding are too apparent to be overlooked, and the comparisons drawn in this paper through the statistical method seem to warrant the following conclusions.

Conclusions

Self breeding of the apple is extremely difficult. Seed produced as the result of selfing are low in viability.

Sib crosses of F_1 seedlings of Salome x Jonathan, and of McIntosh x Longfield can be made with comparative ease. The seeds seem to be in general somewhat less viable than are the seeds produced by out crosses.

Back crosses can be made. The seeds are apparently somewhat higher in viability than are seeds of sib crosses.

Inbreeding, whether by sib crossing or by back crossing, reduces the vigor of the progeny. In many cases this reduction of vigor is so marked that few trees ever make the grade of good orchard trees.

Different lines of breeding vary considerably in germinal constitution as to vigor, and respond differently when inbred. Individual trees of these lines of breeding also respond differently when inbred, or when out crossed, indicating that the factors for vigor are not transmitted in equal doses to all progeny alike in any line of breeding.

In the McIntosh x Longfield line there appears to be a partial dominance for vigor.

The Salome x Jonathan line appears to carry a partial dominance for a lack of vigor.

The range of variation is often more marked in inbred F_2 generation progeny than in progeny of out crosses. To establish purity for vigor, a selection of the phenotypes showing superior vigor must be made for the sib and back crosses in each succeeding generation.

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Fruit Bud Formation and Growth

By H. D. Hooker, *University of Missouri, Columbia, Mo.*

CARBOHYDRATE accumulation is intimately associated with the rest period and with the differentiation of fruit buds in fruit trees. A mathematical study of the simple growth curve has led to certain conclusions which have a direct bearing on these 2 subjects and which aid in the interpretation of data already collected. It has been found that the amount of growth can be expressed by the formula for consecutive reactions derived by Rutherford (Radio-active Substances and Their Relations, Cambridge, 1913. p. 420) to calculate the rate of formation of radio-active substances. It will be observed (1. c. Fig. 99) that the curve representing the formation of radium D by a series of consecutive reactions from radium A, is the

same as the typical growth curve. The formula for this curve has sufficient elasticity that it can be used to describe any simple growth curve with great accuracy. All the formulae that have been proposed for the complete growth curve, namely Mitscherlich's formula, Wilhelmy's formula and Robertson's formula, are special cases of the general formula for consecutive reactions.

These facts suggest that growth may be determined by a series of consecutive chemical reactions that might be represented by the scheme:

$$A \rightarrow u \rightarrow \ .\ .\ \rightarrow x \rightarrow y$$

where *A* is the initial material and *y* the plant substance. If growth were determined by a series of consecutive reactions of this sort, the maximum amount of growth would be determined in all cases by the amount of the initial material. While it is true that the size of a plant may be restricted by limiting the amount of nutrient material, it is not true that the size of a plant can be increased proportionately by any increase in the amount of nutrient material. A pear tree may be dwarfed to the size of a currant bush, but a currant bush cannot be made to grow the size of a pear tree. This difficulty is removed by considering the growth curve to be the curve of a consecutive reversible reaction which might be represented as follows

$$u \rightleftarrows v \rightleftarrows \ .\ .\ \rightleftarrows x \rightleftarrows y$$

This does not involve any change in the formula. The formula for a consecutive reversible reaction is the same as the formula for a consecutive reaction. It is only necessary to re-interpret the meaning of the constants. For a consecutive reversible reaction the maximum amount of growth is determined by the equilibrium value of *y* and not solely by the amount of the initial substance, since the reaction proceeds until an equilibrium is reached.

If we may conclude, therefore, that growth is a consecutive reversible reaction, certain consequences follow. In the first place, an accumulation of the end-products of a reversible reaction retards the rate of the reaction, and eventually stops it. It seems reasonable to assume that carbohydrate is one of the end products of shoot growth, as the leafy shoot is a specialized photosynthetic organ. Carbohydrate accumulation should, therefore, retard and eventually inhibit shoot growth. It is well known that a retarded rate of growth is often associated with carbohydrate accumulation, but it is frequently difficult to decide which is cause and which is effect. There are of course many cases where growth is retarded without there being any accompanying accumulation of carbohydrate, as for example in apple spurs which form terminal buds but do not differentiate fruit buds. In those instances where retardation of growth and accumulation of carbohydrate are closely associated, it does not necessarily follow that carbohydrate is always the cause of the retardation. On the other hand, it is doubtful if any instance can be shown where carbohydrate accumulates in shoots without the rate of growth being retarded. Furthermore, it is very suggestive that carbohydrate

accumulation does not retard root growth, but rather favors it according to the work of Starring (Proc. Am. Soc. Hort. Sci. 20: 288, 1923) and others. Since carbohydrate is in no sense an end product of root development, its accumulation should have no retarding effect on root growth.

The evidence that growth is completely inhibited by large accumulation of carbohydrate is more decisive. The period of inhibited growth known as the rest period is a state that develops gradually, as shown by the increasing severity of the treatments necessary to induce growth and the diminishing vigor of the resulting growth response. Abbott (Bot. Gaz. 76. 167, 1923) has shown that the development of the rest period in young apple and peach trees is accompanied by a gradually augmenting carbohydrate accumulation. Furthermore, any treatment that delays carbohydrate accumulation, such as an early summer pruning of peach trees, delays the rest period. There can be no question here of the rest period causing the accumulation of carbohydrate, as it does not commence until some time after growth has stopped The end of the rest period is associated with a reduction in the amount of carbohydrate. Woody plants have their maximum carbohydrate content in September or October, after which there is a gradual decrease in the carbohydrate content. The great variety of treatments and agents that can be used to break the rest period appear to have but 1 factor in common. As Rosa has pointed out (Proc. Am. Soc. Hort. Sci. 20: 180, 1923), they all stimulate respiration and so bring about a consumption of carbohydrate. It is highly significant that the rest period is confined to those tissues that lead to the formation of carbohydrate—namely to buds and cambium, the roots having no rest period. This situation would be expected if growth were a consecutive reversible reaction, for the accumulation of end products should retard and eventually inhibit the entire series of reactions that lead to the manufacture of carbohydrate.

This suggests an explanation for the coincidence of carbohydrate accumulation and fruit bud differentiation in fruit trees. The assumption that blossoming is always caused directly by the accumulation of carbohydrate seems untenable in view of the investigations of Murneek (Proc. Am. Soc. Hort. Sci. 21: 274, 1924) with tomatoes, where carbohydrate accumulation seems clearly to be a result of the retardation of vegetative growth caused by fruit development. The significance of carbohydrate accumulation which has been found invariably to accompany fruit bud differentiation in apple spurs seems to lie in the inhibition of leaf bud formation. At the time of bud differentiation, a bud must become either a leaf bud or a fruit bud. If growth is a consecutive reversible reaction, it might be expected that the accumulation of carbohydrates in the vicinity of the bud at the time of differentiation would affect the morphological development of the growing point in such a way as to suppress the development of photosynthetic machinery and so favor the formation of floral parts.

Even so, the growth of fruit buds is inhibited by accumulations of carbohydrate, for fruit buds have a rest period as well as leaf buds, though the rest may not be so profound. After all the flower is a metamorphosed shoot.

In apple spurs carbohydrate is stored chiefly in the form of starch and the objection might be raised that this inert material could hardly be expected to exert any material influence on bud differentiation. However, starch is unquestionably in equilibrium with other more active forms of carbohydrate and its accumulation is merely an easily detected index of available carbohydrate accumulation in general.

Relation of Spur Growth to Blossom and Fruit Production in the Wagener Apple*

By J. L. MECARTNEY, *Cornell University, Ithaca, N. Y.*

DURING the last few years there have appeared several papers on the subject of growth and fruiting in the apple. This topic is of particular interest in a consideration of biennial bearing and possible means of overcoming this tendency in certain varieties. Studies by Roberts (6), Hooker and Bradford (3), Auchter and Schrader (1), Mack (4, 5), Hooker (2), and others have done much to throw light on the subject, but a lack of uniformity in the results bearing on the relation of length growth to blossom bud formation seems to justify a further study of that question.

Opportunity for study was afforded in a planting of Wagener trees in the college orchard at Ithaca. These trees by their yield records could be easily divided into 3 rather distinct classes, namely:

1. Those bearing heavy crops in the even years (1922–1924) and practically nothing in the odd years (1921–1923).
2. Those bearing heavy crops in the odd years and practically nothing in the even years.
3. Those bearing a fair crop each year.

This classification was based primarily upon the yield for the years 1921–1924 inclusive, since the regular trees were alternating in the same years as class 2 prior to 1921. The trees were 15 years old in 1924. They were subjected to similar treatments with respect to cultivation, fertilization, cover crops, spraying, etc., but the severity of pruning varied somewhat. However, there appears to be no relation between the pruning practice and the alternation or regularity of the trees, or the year in which they bore their crops, so it is not felt that the difference in behavior could be attributed entirely or even in large part to this cause. And for the purpose of this study it

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would not affect the accuracy of the findings even if the pruning practice did influence the year in which fruit was borne. For if spur length be taken as an index of the fruitful condition the relationship should remain unchanged, irrespective of the pruning practice.

Method of Obtaining Data

It was decided to take for study 3 representative trees in each of the 3 classes mentioned above, the selection to be made upon the basis of yield records. This done, samples for growth measurements were obtained by taking from the spur system of each tree 10 to 15 twigs, two-fifths to three-fourths inch in diameter at the base. The attempt was made to get these as uniformly as possible from all parts of the tree. Twigs from different trees were kept separate so that a detailed study could be made.

Data upon which this paper is based were obtained by measuring every growth on the twig by years from the base up to each of the 1924 growing points. Measurements were made to the nearest millimeter. While record was made of the occurrence and length of cluster bases, the data presented are based only on growth arising from vegetative buds, regardless of whether such buds were terminal or lateral. The age of twigs ranged from 4 to 10 years, the average being about 7.

Average Spur Growth

Before we go into a discussion of the data, it is well to have in mind the exact meaning of the terms used. The term spur, as used in this paper, applies to a growth of 10 centimeters or less. Growths of more than 10 centimeters are called shoots. The "on" year is used to designate the year in which the heavy crop is borne as contrasted to the "off" year when there is little or no crop. This must not be confused with the year of low or high blossom bud formation. Obviously, in a biennial tree, the year in which a high percentage of the growing points form blossom buds precedes the year of heavy blossoming and the fruiting year.

Table I was secured by averaging the spur growths on each tree for each year. Growths of more than 10 centimeters were not included in the average. Considering first the even trees, it is apparent that the average length growth per spur varied in a sort of biennial cycle, the greatest elongation per spur taking place in the off years. The alternation holds rather accurately in the individual trees and in the average. Comparing this to the data for the odd trees it will be seen that here again there is a tendency to alternate in biennial cycles and that the years of greatest growth in the odd trees are the years of least growth in the even. Thus in these odd trees, too, the years of heaviest fruiting are marked by the shortest average spur growth. However, the data for these trees are not nearly as consistent as those for the even trees. The figures for 1921 are higher than we would expect from a comparison with the first 3 trees, and the figures for 1922 are not quite as high as we would expect from such a comparison. A glance at the yield records (Table II) for these trees

shows that they bore a light crop in 1922 while the even trees bore practically nothing in their off years. This relatively heavy crop for the off year is reflected in the growth during that season and the one previous.

The regular trees do not show the alternation characteristic of the biennial trees, though the figures vary somewhat from year to year. The figures for 1919 are higher than we would expect, as that was an on year for the "regular" trees. It has already been noted that the regular trees were in the biennial condition prior to 1921.

The data on the average spur growth are not very conclusive, but they suggest rather strongly that the greatest spur growth takes place in the year when the lightest crop is borne. This is in accord with the studies of Roberts (6), Hooker and Bradford (3), Auchter and Schrader (1) and Mack (5). However, Mack (4) in 1922 and Hooker (2) in 1925 report greater growth in the bearing year. The data of Mack are not directly comparable here, since he included in his average growths of all lengths and in the other studies the averages represent spur growths only.

TABLE I—AVERAGE SPUR GROWTH IN CENTIMETERS

	Tree	1916	1917	1918	1919	1920	1921	1922	1923	1924
Regular trees	C-8	.82	.59	1.35	1.14	.94	.86	.87	.55	.61
	C-9	.62	.47	1.56	1.35	1.09	.72	.74	.87	.30
	D-2	—	.50	1.76	.65	1.24	1.02	.53	.75	.36
	Average	.72	.52	1.56	1.05	1.09	.87	.71	.72	.42
Even trees	C-1	5.00	2.06	.27	1.11	.74	1.01	.43	.95	.27
	D-4	—	—	1.03	1.51	.47	1.07	.37	1.28	.26
	D-9	.20	.59	.39	1.10	.63	1.14	.67	1.55	.26
	Average	2.60	1.32	.56	1.24	.61	1.07	.49	1.26	.26
Odd trees	C-4	.35	.49	1.11	.84	1.09	.72	.75	.45	1.01
	D-1	.38	.75	1.31	.87	1.02	.69	.89	.43	1.07
	D-3	—	.27	1.85	1.27	.80	.78	.84	.37	.92
	Average	.36	.50	1.42	.99	.97	.73	.83	.42	1.00

GROWTH IN LENGTH AND BLOSSOM BUD FORMATION

In Table II the percentages apply to all the growths on which records were taken, irrespective of their length, and the measurements on the 3 trees of a class are considered as a unit. It will be noted in the biennial trees that the alternation from 1 year to the next is very distinct. In other words, almost everything blossomed in the on year, even though the length varied from 1 millimeter to more than 10 centimeters; and practically nothing blossomed in the off year. This is in accord with the findings of Hooker and Bradford (3), Auchter and Schrader (1) and Mack (5).

The inconsistency of the data for the regular and odd trees in 1916 and 1917 may be due in part to the lack of uniformity in the behavior of young trees just coming into bearing. This is rather common in trees at this stage even though they later become distinctly biennial.

There is a tendency especially in the even trees, for the number which do not blossom in the on year to be greater than the number which do blossom in the off year. This tendency has been previously mentioned by other investigators. It is due at least in part to the continuous non-blossoming class of spurs mentioned by Auchter (1). A spur which does not blossom in the on year will very often fail to blossom the next year, but may blossom with the rest in the following on year. Thus the uniformity of behavior of the spurs on a biennial tree is more striking in the off than in the on year.

TABLE II—PERFORMANCE RECORD BY YEARS OF REGULAR AND ALTERNATING TREES

Yield in pounds 1921-1924	Regular trees		Alternating trees: Heavy even years		Alternating trees: Heavy odd years	
Even years	762.0		972.5		159.5	
Odd years	785.5		10.0		905.5	
	A	B	A	B	A	B
1916	16	50.0	6	0.0	41	17.1
1917	131	4.6	40	95.0	77	9.1
1918	187	86.1	101	1.0	92	79.3
1919	308	1.9	160	92.5	150	0.0
1920	466	89.1	327	0.9	222	85.6
1921	724	38.7	410	90.5	437	7.8
1922	1016	23.9	709	0.4	653	76.6
1923	1164	39.9	806	88.3	927	5.9

A—Number of growths studied.
B—Percentage forming blossom buds.

Referring again to Table II, it will be seen that in the odd trees the percentages for the even years are slightly lower than the percentages of other trees during their off year. They may be compared to the figures for the even trees and the figures for the regular trees prior to 1921, as the regular trees were in the biennial condition up to this time. The figure for 1922 may be easily explained, though the reasons for the slight discrepancy in the other figures are not apparent. In this explanation it is first necessary to call attention to the well known fact that the "normal" behavior of a spur in good condition of vigor is to blossom in alternate years, and that successive blossoming is the exception rather than the rule. However, in 1921, successive blossom bud formation did take place in a considerable number of spurs. This accounts in large part for the relatively high figure of 7.8 per cent in 1921 when we should expect a lower figure from a comparison with the data from the other trees. In the case under consideration the successive blossom bud formation was so general over some twigs that they had an on year in 1922. These twigs failed to blossom with the rest of the tree in 1923, but blossomed again in 1924, thus continuing to alternate with the main body of the tree. This accounts for the relatively low figure of 76.6 per cent in 1922 and the relatively high figure of 5.6 per cent in 1923 given in the table. Going back to 1921, there also occurred in this year quite a

a number of cases of successive blossom bud formation scattered throughout many of the twigs. In these instances where the successive spurs were very decidedly in the minority, almost all of them failed to form blossom buds for the next 2 consecutive years, thus conforming to the behavior of the twig as a whole. This in turn may be the reason why the figure for 1921 is higher than that for 1923. It is interesting to note that the year 1921 furnishes practically the only instance in this study where successive blossom bud formation took place.

The points just considered may have some value in clearing up the discrepancies noted in the data on the average length of spur growth in the on and off years.

As has already been noted, the regular trees were in the biennial condition until 1921. Here, as in the case cited above, successive blossom bud formation took place on a very high per cent of the spurs of some twigs, changing their bearing year while others continued to alternate. The result was that about half of the tree began to bear in the even years and the other half continued to bear in the odd years, obviously giving some blossoms each year. The difference between this condition and that already pointed out for the odd trees is simply one of degree. Here, one-half of the tree changed over, giving regular bearing; while with the odd trees a much smaller part changed over, giving a tree which still alternated, though less distinctly than before. The even trees which would normally have set a high percentage of blossom buds in 1921 were unaffected by this factor which caused the others to blossom successively in part. Thus the even trees furnished the most perfect example of biennial bearing.

Obviously the season cannot be entirely responsible for the biennial or annual tendency, since in 1923 the same season produced a set of 5.9 per cent blossom buds in the odd trees, 88.3 per cent in the even, and 39.9 per cent in the regular. Similar variations occur in the different classes in other years.

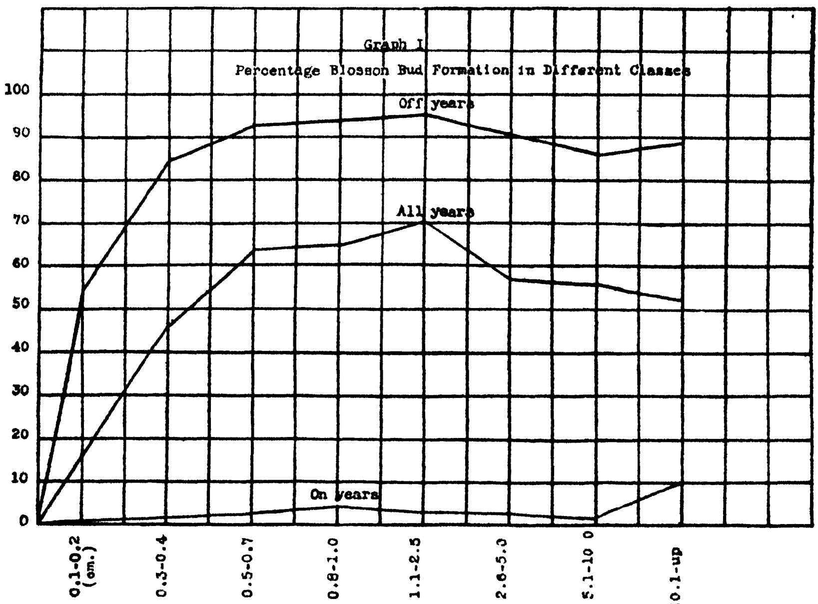
Table III is based upon the same data as Table II, but it is here presented in a somewhat different manner. The growths have been brought together into eight classes upon the basis of length, and the percentage of blossom bud formation determined in each case. In the data for all years, growths of each length class have been grouped together, irrespective of whether they occurred in the on or the off year. These data have been divided into 2 parts by determining for each twig its on and off years, and assembling the data for these separately. By taking the twigs as the unit in this case instead of the tree, it is possible to classify the data from the regular trees into on and off years. Here, as in Table II, blossom bud formation is associated with the off year in all classes, but is almost independent of length. It will be noted that the intermediate lengths tend to have the highest percentage of blossom buds formed in the on years, off years, and in all years. Roberts (6) has previously pointed out the tendency of the medium length and longer spurs to form the highest

TABLE III—GROWTH IN LENGTH AND BLOSSOM BUD FORMATION*

Length (mc.)	0.1–0.2		0.3–0.4		0.5–0.7		0.8–1.0		1.1–2.5		2.6–5.0		5.1–10.0		10.1–up	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
All years	3646	16.3	1837	45.8	1261	63.7	512	64.8	696	70.4	324	57.1	321	55.8	573	52.5
On years	2417	0.7	762	1.8	354	2.8	154	4.5	163	3.1	108	2.8	103	1.9	238	10.1
Off years	1009	54.0	906	84.1	799	92.6	320	93.7	482	95.0	204	90.7	192	85.9	287	88.5

A—Number of growths studied.
B—Percentage setting blossom buds.
*The data for the on and off years are taken from 105 of the 111 twigs studied; data from the other 6 are here omitted since they seemed to alternate in smaller units than those taken for study, and were, therefore, more or less regular. Data for all years include that from all twigs.

percentage of blossom buds in a study of Wealthy in Wisconsin. This tendency has been noted by other investigators. However, it is very apparent from Table III and the graph constructed from Table III that no one length of spur is associated with a certain percentage of blossom bud formation when a succession of years is considered. All classes give a high percentage in the off years, and a low percentage in the on years.



Roberts (6) reports "when the tree is blossoming, practically no spur or secondary growths are of the sizes which form blossoms." In contrast to this the data here presented show 40.5 per cent of the total number of spur growths in the on year to be of a length which in the off year form at least 84 per cent blossom buds. The remaining 59.5 per cent are of a length which in the off year formed 54 per cent blossom buds. Yet the highest blossom bud formation for any class of spur in the on year is 4.5 per cent. Thus the low and high percentage is associated with the on and off year rather than the growth in length. These findings are in accord with those of Hooker and Bradford (3), and Auchter and Schrader (1).

The very short growths show a comparatively low percentage of blossom buds set in the off year. This same condition has been reported in other studies of growth and blossoming, and is probably due in large part to the large number of continuous non-blossoming spurs which fall in this class.

The relatively high percentages in some of the length classes in the on years is largely due to the lack of uniformity in the behavior of

the twigs of the regular trees. Here the factors determining blossom formation are apparently less dominant than in the biennial trees, and permit some individuality in the behavior of very small units or even spurs. Hooker and Bradford (3) found a similar condition in their study in Missouri.

Mack (4) has called attention to the tendency in Wealthy, Baldwin, and Oldenburg for the terminals and spurs on younger wood to alternate with the spurs on the older wood. This suggested an explanation for the 10.1 per cent blossom bud formation in the shoot class in the on year.

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Regularity of Bearing in the Baldwin Apple as Influenced by Fertilizers

By G. F. Potter and S. W. Wentworth, *University of New Hampshire, Durham, N. H.*

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Normal Variation in the Chemical Composition of Fruit Spurs and the Relation of Composition to Fruit Bud Formation*

By C. P. Harley, *University of Maryland, College Park, Md.*

DURING the past 8 or 10 years considerable attention has been directed toward the study of fruit spurs of the apple in connection with some production problems. The nature of this work ranges from general observations to the more detailed studies such as spur measurements and correlations, changes in morphological structure, and chemical composition. Many valuable contributions have been presented by various investigators which have added materially to our knowledge of the fruiting habit of the apple. It would be highly desirable to review the literature dealing with all the phases of fruit spur study. However, time will permit of reviewing only those which have the most direct bearing upon the present investigation and these will be referred to throughout the paper.

Statement of Problem

In connection with fruit spur investigations conducted in Maryland, it seemed desirable to make a study of the chemical changes, especially of carbohydrates and nitrogen, occuring in spurs throughout the year. But before proceeding with these studies the question arose as to how much the normal variation of similar spurs would be in regard to their chemical constituents.

That a variability exists in practically all normal biological activities is universally recognized. On account of variation in material, one might attach significance to values obtained from chemical analysis which are in reality due only to normal variability. In the chemical analysis of fruit spurs it is easy to conceive of such a condition. We know from the work of Roberts (7), Hooker and Bradford (6), Auchter and Schrader (1) and others, that spur performance is in some cases associated with spur lengths. Hence, a sample of spurs might include those of variable lengths and performances which might introduce consequent variation in chemical values obtained. In studying the chemical contents of spurs throughout the year, Hooker (5) found that those spurs about to differentiate blossom buds varied in chemical composition to a marked degree from those forming leaf buds. These studies in Maryland were made to determine, (a) whether the new or old growth of the spur, or both, would be important in determining chemical differences in spurs, (b) the normal variation in chemical content of spurs selected for uniformity of length and age of new and old growth, (c) the normal variation in chemical content of non-uniform spurs of variable length and age.

*Parts of this paper were also presentd to the Graduate School of the University of Maryland in partial fulfillment of the requirements of the degree of Master of Science.

Materials

Materials selected for the variability studies were the vegetative or non-bearing spurs. These were obtained from a 25 year old Stayman Winesap tree located in the College orchard. A study of the past performances of individual spurs showed that the optimum length of new spur growth which produced the largest number of blossom buds in previous seasons was about 25 mm. for Stayman Winesap.

The following types of spurs were collected for analysis, June 27, 1923

(1) Non-bearing spurs of uniform lengths:
   a. new growth 25 mm.
   b. old growth 32 mm. age 3 years.

(2) Non-bearing spurs of variable lengths:
   a. new growth 3 to 100 mm.
   b. old growth 3 to 100 mm. age 1 to 5 years.

Six samples of each of the above types consisting of 30 spurs each were collected. The spurs were divided into 2 parts, (1) growth made in 1923 and (2) growth made in previous seasons. The first was called "new growth" and the second "old growth." These were obtained from all parts of the tree and every effort made to make samples representative.

Collection procedures were conducted as rapidly as possible. Spurs were cut from the tree, the new and old portions divided and placed into separate, previously weighed, wide mouth flasks which were kept tightly stoppered. They were taken immediately to the laboratory and weighed for fresh weight. The spurs were then cut into small pieces and covered with enough hot 95 per cent alcohol to bring the final concentration to 75 per cent, assuming the tissue to contain 50 per cent moisture. To each sample was added .25 gram of anhydrous calcium carbonate, and the flasks then placed in a water bath of 70°C. and maintained at that point for 1 hour. The samples were then stored till analyzed. The materials to be determined by chemical analysis included moisture, free reducing substances, total sugars, total polysaccharides, and starch.

Method of Analysis

In preparing the material for analysis the alcoholic extract was filtered off, and the solid matter dried in an oven at 85 to 90°C. for 48 hours. At the end of this time the dried residue was weighed for oven dry weight and then ground to pass through a 100 mesh sieve. The dry matter in the alcoholic extract was determined by evaporating an aliquot of the extract in an oven at 80°C. to dryness and weighing the residue remaining.

Aliquots of the powdered residue were then extracted for a period of three hours in Soxhlet siphon extraction tubes with 50 per cent alcohol. The alcoholic solution from this extraction was added to a corresponding aliquot from the original preserving alcoholic extract and analysis conducted for the determination of free reducing sub-

stances and total sugars. Total polysaccharide and starch determinations were made from the powdered residue after alcoholic extraction.

The Bertrand modification of the Munson Walker method was used in all sugar determinations.

Free Reducing Substances

The alcohol was removed from the extract on a water bath and water added. The solution was then cleared with neutral lead acetate, excess lead removed with anhydrous sodium carbonate, made up to volume, and filtered. An aliquot of this clear solution was then taken to determine its reducing power. Results calculated as glucose.

Total Sugars

A 50 cc. aliquot of the cleared solution was hydrolyzed with 5 cc. concentrated hydrochloric acid (sp. gr. 1. 183) at room temperature for 24 hours, neutralized with anhydrous sodium carbonate made up to mark, and reducing power determined Results calculated as invert sugar.

Total Polysaccharides

An aliquot of the insoluble residue from the sugar extraction was hydrolyzed by boiling under a reflux condenser in a hydrochloric acid solution (10 cc. concentrated acid in 100 cc. water) for a period of 2½ hours. The mixture was then neutralized with anhydrous sodium carbonate, made up to mark, and the reducing power determined. Results reported in terms of glucose.

Starch

Another aliquot of the insoluble residue from the sugar extraction was taken for the determination of starch. The method used here is a modification of that reported by Walton and Coe (9) of the Bureau of Chemistry, United States Department of Agriculture.

Results

Table I presents the variability which was found in the 6 samples of uniform spurs and in a similar number of samples of non-uniform spurs. The data give the average percentage of 6 analyses with the coefficient of variability for each average. The coefficient of variability represents the per cent variability from the mean of 6 samples.

It will be noted that the non-uniform spurs are much more variable in all constituents than the uniform spurs. This difference is more marked in most cases with old growth of the spur, than with the new growth. Certain constituents show the effect of non-uniformity to a greater degree than others. For instance, the coefficient of variability for percentages of starch in new growth is nearly 6 times as large for non-uniform spurs as for uniform spurs, and the starch in the non-uniform old growth has 4 times as large a coefficient. The percentage of total sugars in new growth of non-uniform spurs shows a coefficient of variability over 5 times the coefficient of sugars in the uniform

TABLE I—VARIABILITY IN SIX SAMPLES OF NON-BEARING SPURS AS EXPRESSED IN TERMS OF THE COEFFICIENT OF VARIABILITY. PERCENTAGES IN TERMS OF DRY WEIGHT

Material analyzed	New growth		Old growth	
	Uniform spurs*	Non-uniform spurs**	Uniform spurs*	Non-uniform spurs**
Average per cent of moisture	60.5	56.9	55.3	56.6
Coefficient of variability	2.19±.427	3.83± .743	1.91± .371	4.94± .958
Average per cent free reducing substances	2.48	2.19	1.94	1.65
Coefficient of variability	3.47±.674	6.89±1 342	19.89±3.870	38.00±7.352
Average per cent of total sugars	3.82	3.03	2.53	3.07
Coefficient of variability	3.02±.588	15.43±3.008	4.86± .934	13.35±2.597
Average per cent total polysaccharides	21.30	21.87	20.81	20.71
Coefficient of variability	.516±.100	1.71± .333	1.41± .274	8.10±1.577
Average per cent of starch	4.30	3.76	2.23	3.06
Coefficient of variability	1.59±.310	8.82±1.720	3.77± .715	14.31±2.785
Average per cent of total carbohydrates	25.12	24.90	23.34	24.78
Coefficient of variability	.562±.107	2.004± .391	.999± .194	7.73±1.484

*Six samples of spurs, each new growth being exactly 25 mm. in length and each old growth being exactly 32 mm. in length, and each old growth 3 years of age.
**Six samples of spurs taken without regard to length of new growth or length and age of old growth.

spurs. The total polysaccharides and total sugars in the old growth are likewise greatly influenced by non-uniformity. The non-uniformity of the spurs in a sample as regards length and age of growth thus can introduce a considerable error in the results of chemical analyses. Considering only the new growth of uniform spurs the data show small variabilities which are probably within the experimental error due to the analysis.

This shows that a chemical analysis of such material can be made with an assurance of giving a reliable measure of internal conditions.

A very striking feature of the data in Table I is the large variability of constituents in the old growth with both uniform and non-uniform spurs, although much greater variability occurs in the latter group. The free reduçing substances and starch show large coefficients of variability, especially with the non-uniform spurs. It can easily be seen that the inclusion of non-uniform old growths with the new growth in a sample for chemical analysis, even though the new growth was uniform, would subject the results to a large error. Large differences would be necessary to render the data significant from such material.

In view of the above results, spur samples should be selected for uniformity of growth and age, and the new growth should be separated from the old growth. Further, the greater variability of materials in the old growth indicates that analyses of the old growth would be less reliable for the purpose of interpretation of results.

Carbohydrate and Nitrogen Content of Fruit Spurs at Various Periods of the Year

Uniform samples of fruit spurs were collected at 5 different periods of the year for the purpose of studying changes in carbohydrate and nitrogen content. A knowledge of these changes which occur in the spur might bring about a better understanding of the internal conditions prior to and accompanying fruit bud differentiation, fruit setting, and the development of the fruit.

The materials for this study were spurs falling into the two general spur classes, (1) vegetative or non-bearing spurs possessing terminal buds which should differentiate into blossom buds for the following year, (2) bearing spurs which have blossoms or fruit during the growing season and a secondary vegetative shoot forming a terminal leaf bud.

Group	Type	New growth Length in mm.	Old growth Length in mm.	Age of old growth
I	Non-bearing	25 mm.	32 mm.	3 years
II	Bearing	32 mm. including cluster base	32 mm.	3 years

Composite samples were taken from four Stayman trees 25 years old which had been moderately heavy bearers annually. These trees shared the same location in the orchard and were very uniform as to

size, vigor and productiveness. Sampling dates were as follows:—June 27, 1923; August 8, 1923; December 17, 1923; May 14, 1924; and July 9, 1924. All collections were made on clear days which had been preceded by one or more clear days. The number of spurs comprising a sample ranged from 150 to 180. Each sample contained only accurately uniform spurs as to length of new growth and length and age of old growth.

The optimum length of non-bearing spurs producing the largest number of blossom buds was found, for Stayman Winesap trees in Maryland, to be 25 mm. In the case of bearing spurs 25 mm. was selected for the length of the secondary shoot, but the addition of the cluster base increased this measurement to about 32 mm. The number of years selected for the old growth was purely arbitrary.

Methods of collection and preservation were identical with those already described, except (1) the samples were not taken in replicates and contained from 150 to 180 spurs each. (2) Leaves were removed and placed in previously weighed paper bags for the purpose of obtaining comparative leaf weights and areas of each of the 2 classes of spurs. Substances to be determined by chemical analysis were, the various carbohydrates, alcohol soluble nitrogen, alcohol insoluble nitrogen, and total nitrogen.

Methods of Analysis

Carbohydrates: The methods for carbohydrate analysis were the same as previously described.

Sucrose and Polysaccharides other than Starch: The difference between free reducing substances and total sugars was considered sucrose, and the difference between starch and total polysaccharides as polysaccharides other than starch.

Alcohol Soluble Nitrogen: An aliquot of the combined alcoholic extracts was transferred to a Kjeldahl flask, the alcohol and water driven off on the water bath, and nitrogen determined by the Gunning-Kjeldahl method.

Alcohol Insoluble Nitrogen: Nitrogenous substances present in the residue which are insoluble in hot alcohol were determined by the Gunning-Kjeldahl method.

Total Nitrogen. The combined percentages of soluble and insoluble nitrogens calculated as per cent of total nitrogen.

Results of Leaf Measurements and Chemical Analysis

Results of measurements and weights of spur leaves collected June 27, 1923 are to be found in Table II.

TABLE II—Average Leaf Area per Spur in Square Inches

	Non-bearing spurs	Bearing spurs
Average leaf area in square inches	31.10	16.13
Average weight of leaves per spur in grams	3.37	1.98
Number of leaves per spur	7.1	7.6

Analogous to the findings of Bradford (3), Gourley (4), Barker and Lees (2), and others, non-bearing spurs, those about to differentiate fruit buds, possess almost twice the leaf area of the bearing spurs, those producing leaf buds. The weights of the leaves show a similar difference. However, the actual number of leaves is greater on bearing spurs than on the non-bearing. This is probably due to the increased number of small leaves about the cluster base.

Associating chemical content in Table III with spur leaf area (Table I) at the time of fruit bud differentiation, shows a positive correlation between leaf area and the percentage of carbohydrates present in the spur. This correlation is most pronounced when starch alone is compared with leaf area.

In Tables III and IV are presented the percentages of dry matter, free reducing substances, sucrose, total sugars, starch, polysaccharides other than starch, total polysaccharides, total carbohydrates, soluble nitrogen, insoluble nitrogen, and total nitrogen found in the new and old growths of bearing and non-bearing spurs at the dates indicated. These are given in terms of dry weight. All determinations were run in duplicate and each value represents the average of 2 check analyses. Unfortunately the December 17 collection of bearing spurs had to be omitted due to the lack of sufficient spurs of this uniform class to complete a sample.

Examination of the tables shows that both bearing and non-bearing spurs vary in chemical composition at different times of the year. However, a wide difference can be seen to exist at same dates between non-bearing and bearing spurs. This is particularly true of the new growths. Changes in the various constituents of the old growths are not especially marked. In fact, in these results it is questionable if the data obtained from old growth analysis can be of much importance in the correlation of chemical content with spur response. In view of this, more attention should be paid to new growth analyses. The percentages of materials found in the spurs follow, in a general way, the findings of other investigators.

Carbohydrate Changes

In comparing the new growth contents of non-bearing and bearing spurs a striking contrast can be seen in the various carbohydrates at the time of fruit bud differentiation. It will be noticed that the analyses of samples taken in consecutive years at the time of fruit bud differentiation (June 27th, 1923, and July 9th, 1924), show approximately the same differences between non-bearing and bearing spurs. In every case the percentage of the different carbohydrates in the new growth of non-bearing spurs is greater than in the new growth of bearing spurs. Attention is called to the greater percentage of reducing sugars in non-bearing spurs, and this is closely associated with a greater percentage of sucrose. The most pronounced difference at fruit bud differentiation time, however, is to be found in the case of starch, where we have in non-bearing spurs a percentage approximately 4 times greater than in bearing spurs.

TABLE III—CARBOHYDRATES AND NITROGEN PRESENT IN NEW GROWTHS OF SPURS AT VARIOUS TIMES OF THE YEAR. PERCENTAGES IN TERMS OF DRY WEIGHT

	Dry matter	Free reducing substances	Sucrose	Total sugars	Starch	Polysaccharides other than starch	Total polysaccharides	Total carbohydrates	Soluble nitrogen	Insoluble nitrogen	Total nitrogen
NON-BEARING											
June 27, 1923. .	38.85	2.48	1.34	3.82	4.30	17.99	21.29	25.11	—	—	—
August 8, 1923. .	45.80	1.37	1.20	2.57	9.39	13.66	23.10	25.70	.55	1.06	1.61
December 17, 1923	47.30	2.95	3.57	6.52	3.30	15.70	19.00	25.50	.12	1.28	1.40
May 14, 1924. . .	40.20	2.21	1.94	4.15	1.66	16.10	17.80	20.20	.53	1.47	2.00
July 9, 1924. . . .	42.10	2.01	1.48	3.49	4.00	16.90	20.90	24.40	.51	1.73	2.24
BEARING											
June 27, 1923. . .	37.44	1.73	.66	2.39	.89	17.83	18.74	21.13	—	—	—
August 8, 1923.	40.70	1.39	1.37	2.76	4.82	18.08	21.90	24.70	.33	1.17	1.50
December 17, 1923	—	—	—	—	—	—	—	—	—	—	—
May 14, 1924. . .	37.40	1.65	2.00	3.65	1.44	16.60	17.00	20.65	1.30	1.72	3.02
July 9, 1924.	38.30	1.73	.84	2.57	1.02	17.98	19.60	21.60	.82	1.48	2.30

TABLE IV—CARBOHYDRATES AND NITROGEN PRESENT IN OLD GROWTHS OF SPURS AT VARIOUS TIMES OF THE YEAR. PERCENTAGES IN TERMS OF DRY WEIGHT

	Dry matter	Free reducing substances	Sucrose	Total sugars	Starch	Polysaccharides other than starch	Total polysaccharides	Total carbohydrates	Soluble nitrogen	Insoluble nitrogen	Total nitrogen
NON-BEARING											
June 27, 1923	44.70	1.94	.59	2.53	2.23	18.60	20.80	23.30	—	—	—
August 8, 1923	46.30	1.41	1.02	2.43	2.68	18.90	21.60	24.00	.16	.72	.88
December 17, 1923	50.50	4.49	3.11	7.60	2.76	16.90	19.70	27.30	.32	1.09	1.41
May 14, 1924	41.00	2.40	.87	3.27	1.88	19.40	21.30	24.60	.30	1.02	1.32
July 9, 1924	44.00	1.46	.73	2.19	2.08	19.00	21.10	23.29	.22	.34	.56
BEARING											
June 27, 1923	45.30	2.09	.46	2.57	2.13	17.60	19.80	22.30	—	—	—
August 8, 1923	46.00	1.96	.94	2.90	1.03	20.50	21.50	24.40	.17	.87	1.04
December 17, 1923	—	—	—	—	—	—	—	—	—	—	—
May 14, 1924	42.00	1.66	1.14	2.80	1.19	18.60	19.80	22.60	.47	.86	1.33
July 9, 1924	45.70	2.12	.52	2.64	2.24	18.30	20.50	23.10	.34	1.04	1.38

From June 27 to August 8, starch increases in both bearing and non-bearing spurs, but the non-bearing spurs have about twice the percentage of starch compared to the bearing spurs at this date. With the non-bearing spurs it is probable that fruit bud differentiation is occuring during all this period. In contrast to this accumulation of starch, there is a decrease of soluble sugars in the non-bearing spurs while in the bearing spurs there is a slight increase of total sugars but a decrease in free reducing substances.

The starch content of the old wood is practically the same in both classes of spurs at fruit bud differentiation time, although during the remainder of the year there is a steady total reserve in the non-bearing spurs, while it is decreased in the bearing.

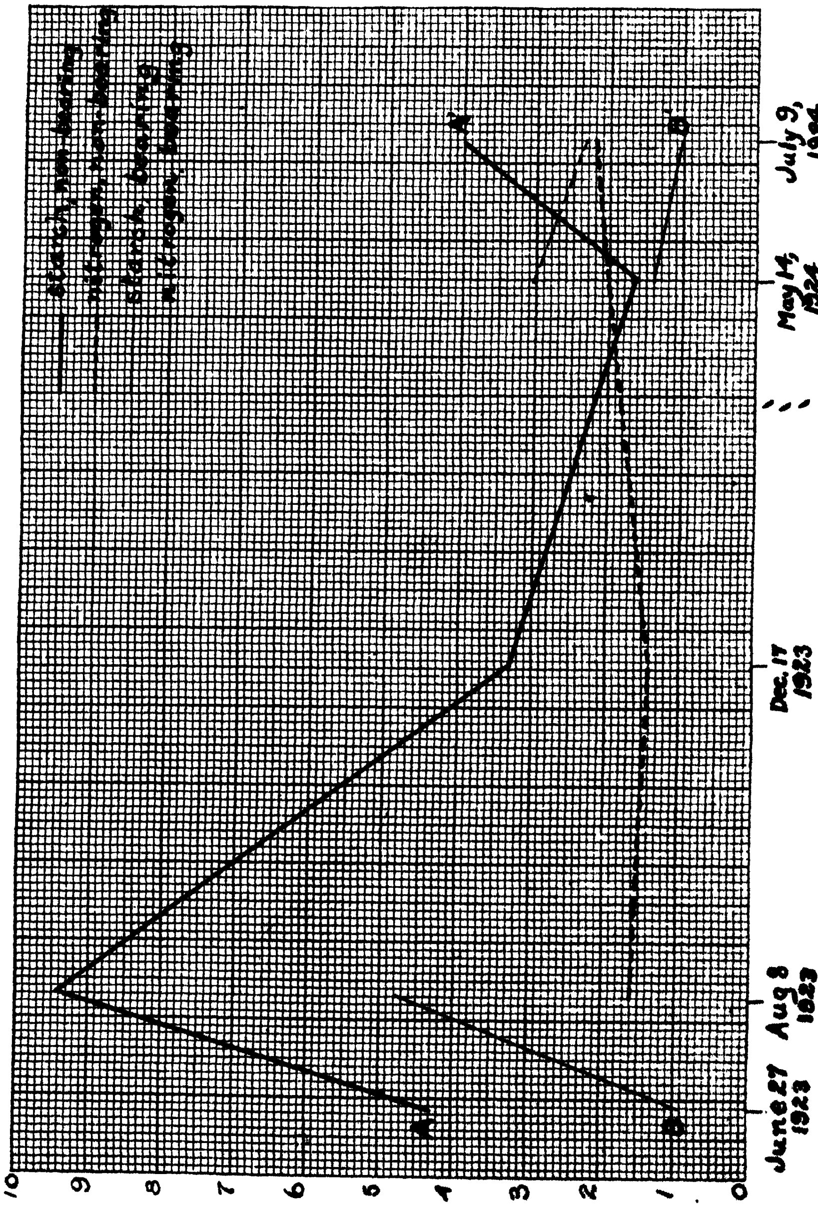
Analyses of December 17 show a great decrease of starch in the new growth of non-bearing spurs. This decrease of starch is accompanied by an increase of free reducing substances and total sugars, the percentage of total carbohydrates remaining the same. There is also an increase of the soluble sugars at this date in the case of the old growth of non-bearing spurs, however, there appears no loss of starch, but instead the polysaccharides other than starch are decreased. Although no samples of bearing spurs were taken at this date, evidence presented by Hooker (5) leads us to believe that these spurs would probably show a maximum in soluble sugars and minimum in polysaccharides at this time of the year.

This decrease of polysaccharides and corresponding increase of sugars is evidently an hydrolysis of polysaccharides which may be associated with temperatures in winter. Schrader (8), in Maryland, noticed this same change in grape canes January 11, 1924, and Boswell also in Maryland (unpublished) found a similar hydrolysis to occur in cabbage at the same date.

Relation of Carbohydrates to Nitrogen in Bearing and Non-Bearing Spurs

In the non-bearing spurs at fruit bud differentiation time in both seasons, we find the percentages of carbohydrates quite high in proportion to total nitrogen, and this ratio is magnified if interpreted in terms of a starch-nitrogen ratio. Hooker (5), in studying seasonal changes in the chemical composition of apple spurs, placed special emphasis upon the starch-nitrogen ratio and the amount of starch as being most indicative at the time of fruit bud differentiation. In general, results obtained in the present investigation correspond closely to those obtained by Hooker despite the fact that a different variety was used and only new growth analyses are considered to be significant.

The relative positions occupied by starch and total nitrogen of the new growth of bearing and non-bearing spurs at different times of the year, are shown by the chart. It will be noticed that at the time of fruit bud differentiation 2 points of high starch in relation to nitrogen appear in non-bearing spurs (A and A^1). In the bearing spurs, the percentage of starch is much less than in non-bearing spurs


Starch, non-bearing
nitrogen, non-bearing
Starch, bearing
nitrogen, bearing
June 27 1923
Aug 8 1923
Dec. 17 1923
May 14, 1924
July 9, 1924
A
B
0
1
2
3
4
5
6
7
8
9
10

(B and B[1]), and the relation of starch to nitrogen is reversed as shown in 1924. Special attention is called to the fact that 2 critical points for fruit bud differentiation appear on the starch curves, and practically the same values are obtained in both years.

Nitrogen Changes

Possibly the most outstanding feature of the nitrogen analysis is found in samples taken May 14. There appears a high nitrogen content in the new growth of bearing spurs immediately following the time that these spurs are setting their fruit, in comparison to non-bearing spurs. The soluble nitrogen of the bearing spurs is markedly greater at this time and the insoluble nitrogen is also somewhat greater than in the non-bearing spurs. No doubt the percentage of nitrogen was also high at fruit setting (one week earlier), but no analyses were made. The relatively high content of nitrogen, especially soluble nitrogen, emphasizes the role of nitrogen in the blossoming spurs. This may suggest why spring applications of readily available nitrogen are beneficial in many cases in increasing the set.

The nitrogen content of old growth of bearing spurs at fruit-bud differentiation time is higher than the non-bearing spurs.

Conclusions

1. A much higher coefficient of variability was found in the chemical content of samples of spurs of variable lengths and age than in samples of spurs which were accurately uniform in length and age. Thus the reliability of spur analysis may depend upon the uniformity of spurs selected for samples.

2. A higher variability was present in the old growths than in the new growths. When old growths of spurs are included in spur samples, there is introduced a variable factor which may obscure significant differences which might exist in the new growth.

3. At the time of fruit bud differentiation, non-bearing spurs possessed almost twice the leaf area and weight as bearing spurs, although the number of leaves was greater on the bearing spurs due to many small leaves on the cluster base.

4. In studying seasonal changes in chemical composition, between old growths of bearing and non-bearing spurs the differences were not as clearly defined as between the new growth of bearing and non-bearing spurs.

5. The high sugar and starch content of the new growth of non-bearing spurs at differentiation time lends further evidence to the conception of the importance of these substances in their relation to fruit bud formation. The starch values show the most striking contrasts in this connection. There is also a correlation existing between leaf area, starch content, and fruit bud formation.

6. The accumulation of starch from June to August may favor fruit bud differentiation throughout this period.

7. The decrease of starch and other polysaccharides, with a corresponding increase in free reducing substances and total sugars, in

samples taken December 17, indicates a hydrolysis of acid hydrolyzable materials related possibly to low temperatures.

8. A high percentage of nitrogen is present in new growths of bearing spurs immediately following fruit-setting. This is particularly noticeable in the case of soluble nitrogen. No doubt the percentage of nitrogen was also high at fruit setting (one week earlier), but analyses were not made.

9. Dry matter increases uniformly in all classes and divisions of spurs as the season progresses.

10. Non-bearing spurs at fruit bud differentiation time are relatively high in starch compared to nitrogen content, while bearing spurs at the same period are relatively low in starch compared to nitrogen content.

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Fruit Spur Composition in Relation to Fruit Bud Formation

By G. F. Potter and H. R. Kraybill, *University of New Hampshire, Durham, N. H.*

IN COLLABORATION with other members of the New Hampshire Station staff, the writers have recently published results of an extensive study of the relation between fruit bud formation and composition in apple fruit spurs. Non-bearing spurs from trees in a plot which is cultivated and received in addition a generous annual

application of nitrate of soda, showed a fair accumulation of carbohydrates, and considerable amounts of nitrogen and water. These spurs formed fruit buds abundantly. It is assumed, therefore, that they were in class III, as suggested by Kraus and Kraybill (4), in which the carbohydrate nitrogen ratio is balanced, vegetation is moderate, and the plant is fruitful.

In non-bearing spurs from unfertilized trees standing in sod, there was a relatively high accumulation of starch and carbohydrates, but the water and nitrogen were relatively low. Only a few fruit buds were formed. It appears, therefore, that these spurs were in or approached the condition of class IV in which the plant is relatively non-vegetative, non-fruitful and high in carbohydrates in relation to the nitrogen present. No non-bearing spurs were analyzed which could be assumed to be in class II; namely in an over-vegetative and non-fruit bud forming condition because of too high nitrogen supply in relation to the carbohydrates.

As has been found by other investigators, bearing spurs, which formed practically no fruit buds, showed more nitrogen and water and less carbohydrates in each case than the non-bearing spurs from the same or similar trees. The most interesting point is that *the bearing spurs from the sod plot having relatively more nitrogen and less carbohydrates than the non-bearing spurs on the same trees, were essentially the same in composition as the non-bearing spurs from the nitrogen plot which were assumed to be under good conditions for fruit bud formation.* It is possible that within the spur there is a localization of the food materials such that the actual chemical environment of the terminal buds on the secondary shoots of the bearing spurs was not the same as that of the terminal buds on the non-bearing spurs even though the average composition for the two sets of spurs was almost identical. It is also possible that, although similar in total amount, the nature of the nitrogen supply was different in the 2 cases. It appears to us, however, that the question of "dominance" should be considered.

While there is by no means agreement as to the mechanism involved, it is well known that the terminal bud of any shoot has an inhibiting effect upon the development of lateral buds. Child (1), who has conducted extensive investigations in this field, states that this "dominance" may be asserted not only by a bud, but by any region of high metabolic activity. On a bearing spur the region of greatest growth and highest metabolic activity must be in the growing fruit and it is, therefore, possible or even probable, that this retards development of the secondary shoot and its terminal bud. That this is the case appears to be supported by the well known facts that length growth is usually short in secondary shoots on bearing spurs and that leaf development which begins earliest on fruiting spurs is significantly less than on non-bearing spurs.

Gardner (2) has presented evidence that "dominance" is affected through changes in food movement. Nevertheless, we believe that one cannot analyse bearing and non-bearing spurs and assume that

the differences in composition found are responsible for the differences in fruit bud formation observed. There are only a few instances in recent literature in which the composition and performance in fruit bud formation of similar spurs can be compared. in which the disturbing influence of a developing fruit is not present.

At the Oregon Station, Harvey (3) has analyzed spurs all of which had bloomed, but none of which carried fruit subsequent to the middle of June. Here it was found that defoliation significantly decreased the total carbohydrates and increased the nitrogen supply. At the same time fruit bud formation was reduced from about 40 to approximately 8 or 10 per cent. It is assumed that the defoliated spurs were moved from the moderately vegetative and fruitful class III toward the vegetative class II in which nitrogen is high and carbohydrates low. Harvey has calculated the ratio between the total carbohydrates and the total nitrogen present in his spurs and it is of interest to note that his spurs which were assumed to have too high nitrogen and too low carbohydrate content on this basis of comparison, are almost identical with the spurs which were found most fruitful in the New Hampshire experiment. Also the mathematical carbohydrate nitrogen ratio of the spurs which Harvey found most fruitful is almost exactly similar to that of the non-bearing spurs from the sod plot of the New Hampshire experiment in which fruitfulness was reduced. In interpreting the New Hampshire results it was assumed that these spurs have too great an accumulation of carbohydrates and were in a condition approaching class IV. It can scarcely be expected that results of the accuracy of these analyses can hold with mathematical exactness. In Harvey's results there is evidence that the optimum ratio may vary with the variety. There is also a possibility that under different climatic conditions the optimum composition would not be the same.

In results reported by Hooker (4), the major difference between barren spurs of Ben Davis and Nixonite and non-bearing spurs of fruitful trees was found to be that the barren spurs were lower in starch on June 26. Without counts as to the actual number of fruit buds formed by these spurs and with the differences depending on analysis at only one date during the season, it is precarious to draw conclusions, but it might be assumed that these spurs did not form flowers because the nitrogen supply was too high in relation to carbohydrates. In other words, they might be considered to be in the vegetative class II of Kraus and Kraybill.

Kraybill (6) has analysed non-bearing spurs from young McIntosh trees in some of which a greater concentration of carbohydrates and a decrease in nitrogen content were effected by ringing. The spurs on the ringed trees produced more flowers. Starch accumulation in these more fruitful spurs was practically as high as in Baldwin spurs assumed to have too high a carbohydrate nitrogen ratio, but the nitrogen content of the McIntosh spurs was considerably higher than that of the sod Baldwins so that the carbohydrate nitrogen relations were probably more favorable.

The question of the time of fruit bud formation is very important in connection with the study of relation of composition of spurs to their performance. While we have attempted to compare results of different experiments, we do not know with any degree of exactness at what time fruit buds were formed in the several cases. The analyses were made only a few times in most cases and there is no assurance that these sampling dates are representative of the same stage of seasonal development. Consequently, it is extremely difficult to compare results of different workers in different sections of the country.

In the New Hampshire experiments no significant differences in carbohydrate composition of the spurs were found which could be correlated with the per cent of fruit buds formed except in the content of relatively inert substances such as starch. The differences observed were found to be at a maximum relatively late in the season. Therefore, it is possible or even probable, that these differences in chemical composition are not the cause of the differences in fruit bud formation, but are merely associated phenomena due to the same physiological cause.

It is evident that the data as yet available are too meagre to permit drawing definite conclusions. If the interpretation of the behavior of bearing as compared to non-bearing spurs which is here suggested is correct, investigators will do well in the future to avoid the difficulties due to "dominance." The greatest light would be shed upon this problem by analysis of considerable numbers of different lots of *non-bearing* spurs, to determine the relation between composition and spur performance *in the absence of a disturbing influence of a developing fruit.* Analysis of apical and basal portions of spurs may reveal important differences in localization of food materials. In comparing different lots of non-bearing spurs more accurate results may be expected if the sample is restricted to the new growth. Where it is feasible, microscopic examination of a random sample of buds at each sampling date to determine the relative stage of fruit bud development on the different plots, would be extremely desirable.

It is unfortunate that the amount of nitrogen present in the spur is very small and the determination of the different forms is a difficult or impossible task. It is believed that if progress can be made in differentiating the forms of nitrogen available to the spurs, it will be of great value in interpreting results.

In the preliminary experiments at New Hampshire, samples were taken at close intervals throughout practically the entire growing season. The curves obtained indicate that a fair index of the differences between different series of spurs might have been obtained from a relatively small number of samples taken during July and early August.

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The First Year's Effect of Different Nitrogen Fertilizers on Bearing Apple Trees Low in Vigor

By A. LEE SCHRADER and E. C. AUCHTER, *University of Maryland, College Park, Md.*

THE use of nitrogen fertilizers for orchards has become such an important practice in many localities that a detailed study of the comparative effects of various nitrogen carriers is becoming more and more important. Orchardists are continually asking the question as to the most desirable material to employ where nitrogen deficiency is apparent. Experiments over the country have shown decisively the value of nitrate of soda in orchards of low or medium vigor, in increasing the set of apples and in promoting growth of the trees, and reports also come from orchardists and experimental stations of similar benefits from the use of sulphate of ammonia. However, few detailed studies have been reported for fruit trees to actually show the relative merits of these 2 materials.

In view of the extensive use of nitrogen fertilizers in Maryland, it was deemed advisable to find out, if possible, whether or not both materials could be used to the same advantage under all conditions of soil and orchard. Such a study to be complete involved the use of orchards of various ages and kinds on different soil types. Fertilizer experiments involving the use of nitrate of soda and ammonium sulphate on several peach and apple orchards over the state of Maryland, have been in progress for 4 years, and some of the observations and data from these experiments will be used in this paper. However,

the experiment detailed below is limited to the first season's response of 20 year old York Imperial apple trees which were growing in sod undoubtedly deficient in nitrates as evidenced by the poor growth of the trees, compared to nearby York Imperial trees under cultivation. These nitrogen starved trees were selected for this work because it was felt that the marked responses to nitrogen from such trees would afford a better opportunity for comparison of the 2 sources of nitrogen. Previous observations in 1922 in a different orchard showed a marked difference in response of spur growth and foliage color in favor of nitrate of soda compared to ammonium sulphate when these materials were applied in the spring on poorly growing StaymanWinesap trees on a sandy soil. Trees in rows to which lime had been added to correct any acidity, gave no better response to ammonium sulphate than trees in rows which received ammonium sulphate without the addition of lime. Such lack of beneficial results from the use of lime in addition to the ammonium sulphate was shown in 7 different orchards growing in different parts of the state under a wide range of soil conditions.

Outline and Methods of Experiments

The plots of York Imperial used for comparison had received uniform treatment for 5 years, and showed uniform behavior of growth and yield according to data recorded during this period. All plots had been thoroughly limed 4 years previous to these special nitrogen studies. Each plot consisted of a row of 12 trees. The various plots received 5, 10, 15, or 20 pounds of nitrate of soda per tree, or equivalent amounts of ammonium sulphate per tree. Some plots had these amounts applied in the fall (September 16, 1924), other plots received applications in the following spring (March 25 to 27, 1925), and still other plots received an equal dosage in the fall and spring. Duplicate plots were made of many of the treatments. Adjacent rows or rows with only 1 row separating them were compared. In addition to the different amounts and kinds of nitrogen added, 10 pounds of acid phosphate were applied about each tree in the experiments. Samples of spurs for chemical analyses were taken from 2 trees of each of the following plots:—

1. 10 pounds sodium nitrate in the fall.
2. 10 pounds sodium nitrate in the spring.
3. 7.5 pounds ammonium sulphate in the spring.
4. 7.5 pounds ammonium sulphate in the fall.
5. Check trees in sod.
6. Check trees in cultivation.

The trees selected in each plot had approximately 75 per cent of bloom and were located in similar positions in the plots. One-hundred spurs were taken from the upper part of each tree at each sampling which made a composite sample of 200 spurs for each plot. Spurs were selected carefully for uniformity of growth, especially that the 1924 growth was approximately one-half inch in length. Harley (3) has shown at this Station that it is very important to select spurs of

uniform new growth for chemical studies. Spurs on small, weakly growing branches which are found on the older parts of the tree were not taken.

The leaves were removed from each spur; then each spur was separated into new growth, one-year wood and old wood, and placed in weighed flasks. The old wood was broken into small pieces. Each portion of the spur sample was then covered with hot 95 per cent alcohol and refluxed at 70°–75° for one hour. A packing house in the orchard served as a field laboratory since the orchard is located 100 miles from the College. Sterno heat was used satisfactorily in heating the water baths.

Spur samples were collected on April 20 and June 27, 1925. The April 20 samples included only blossoming spurs, and the blossoms were included with the new growth. On June 27, samples were taken of fruiting spurs, having one apple each, and of non-fruiting spurs which had not set at pollination time. Apples were carefully removed from the fruiting spurs with a knife. Only spurs of uniform new growth about one-half inch were used in the June samples.

Analyses were made of these samples for total nitrogen, alcohol soluble nitrogen and insoluble nitrogen. The Kjeldahl method with a modification by Gunning, Jodlbauer and Forster, to include nitrates was used in this work. A 3 hour extraction with hot 50 per cent alcohol in a Soxlet siphon extraction apparatus was made on finely ground solid material to separate the alcohol soluble nitrogen from insoluble nitrogen.

Data Secured

Observations of the color of the foliage and general growth were made several times during the season, and growth records were secured at the end of the season.

Twenty terminal growths from each tree about 6 feet from the ground were measured to the nearest centimeter using care to obtain growths uniformly from all sides of the tree. Trunk circumference of each tree was obtained at a point half way from the ground to the lowest limb. Similar measurements have been made each year during the past 4 years.

The 1925 growth of 500 spurs per tree was carefully measured in millimeters on several trees of the same size which had borne similar crops in 1925, and were located adjacent to one another. Growth of fruiting spurs and continuous non-blossoming spurs were not included. *Spur measurements were secured on the same trees from which spur samples were taken for chemical analysis.*

Results of Observations of Color of Foliage

Both nitrate of soda and ammonium sulphate plots showed markedly greener foliage than the check trees, but differences between treatments were also noticeable. Observations were made at several dates with similar results.

On May 31, spring nitrated plots had greener foliage than spring sulphated plots regardless of amounts of application, and the same

difference held for fall applications, but spring application of either material resulted in better color than fall application of either material. The larger the amount of application the greener the foliage appeared. Dr. W. H. Chandler of California and Mr. G. L. S. Carpenter of the American Fruit Growers, Inc., accompanied E. C. Auchter when these observations were recorded.

On June 30 the same differences were noted by the authors as those seen on May 31 with the exception that 15 pounds of ammonium sulphate at this later date showed a response in foliage color equivalent to 20 pounds of nitrate, and 11¼ pounds of ammonium sulphate resulted in an equal response of foliage color as 15 pounds of nitrate. Thus the large amounts of either material were equal in affecting the *color* of foliage, but smaller amounts showed more color from nitrate of soda.

On July 22 the differences were the same as noted on June 30. Again on September 4 these same differences were recorded. At this later date several horticulturists were present including Professor W. H. Alderman, Dr. A. J. Heinicke, Dr. L. H. McDaniels, Dr. D. B. Carrick, Professor Joseph Oskamp, Professor G. F. Potter and Mr. G. S. L. Carpenter.

Summing up these observations, it appears that a marked response in foliage color followed applications of both nitrate of soda and ammonium sulphate. Spring applications of either materials resulted in greener foliage than fall applications. Greener foliage occurred on spring nitrated trees than on spring sulphated trees, and likewise on fall nitrated trees compared to fall sulphated trees until mid-season when large amounts of either material showed an equal effect upon color of foliage.

Results of Growth Studies

The data given in Table I show the marked response of these poor growing trees to nitrogen applications. Where no fertilizers were applied the growth of terminals, trunk and spurs is very much less than the growth recorded for the fertilized trees. In fact the growth of all the trees before treatment was of the same magnitude as noted for these check trees. Hence, the increased growth following nitrogen applications is about 200 to 300 per cent greater than growth in previous seasons.

By arranging the treatments for comparison of nitrate of soda and ammonium sulphate, it will be seen in Table I that nitrate of soda has shown consistently greater average growth of terminals, trunk and spurs. These differences were found to be significant in all cases, except the increment of trunk circumference for 2 treatments. Terminal growth of the nitrated trees is greater in all the comparative treatments, and the difference in favor of nitrate is always significant. Spur growth measurements, likewise, show significant differences in favor of nitrate of soda.

Thus it can be seen that average spur growth was about 60 per cent greater on those trees receiving 10 pounds of nitrate of soda in the spring compared to those trees receiving 7½ pounds (equivalent

nitrogen content) of ammonium sulphate in the spring. On the basis of increase over the checks, the spring nitrated trees show increase of spur growth amounting to 150 per cent, while spring sulphated trees show only 53 per cent increase of spur growth.

When 20 pounds of sodium nitrate and 15 pounds of ammonium sulphate per tree were used the difference of spur growth in favor of nitrate was only 21 per cent. Thus when greater amounts of ammonium sulphate are used, sufficient amounts of nitrogen may be available early enough to cause good spur growth.

TABLE I—Showing the First Season's Effects of Sodium Nitrate and Ammonium Sulphate on the Growth of Weakly Growing York Imperial Apple Trees in Sod

Treatment	1925 Terminal growth in cm.	1925 Circumference increment in inches	1925 Spur growth in mm.
10 pounds sodium nitrate—spring	12.56	1.536	11.85±.17
7.5 pounds ammonium sulphate—spring	9.49	1.143	7.30±.12
Difference	3.07	0.393	4.55±.207
Odds (Students)	50.8 to 1	284.7 to 1	——
20 pounds sodium nitrate—spring	20.32	1.604	14.08±.31
15 pounds ammonium sulphate—spring	15.27	1.187	11.58±.28
Difference	5.05	0.417	2.50±.42
Odds (Students)	197.1 to 1	85.2 to 1	——
10 pounds sodium nitrate—fall	13.22	1.525	9.84±.17
7.5 pounds ammonium sulphate—fall	9.17	1.087	8.98±.15
Difference	4.05	0.438	0.86±.23
Odds (Students)	89.1 to 1	302 to 1	——
20 pounds sodium nitrate—fall	19.43	1.554	——
15 pounds ammonium sulphate—fall	11.70	1.286	——
Difference	7.73	0.268	——
Odds (Students)	242.9 to 1	5.1 to 1	——
Sodium nitrate—5 pounds fall—5 pounds spring	13.80	1.437	——
Ammonium sulphate—3.75 pounds fall—3.75 pounds spring	8.50	1.156	——
Difference	5.30	0.281	——
Odds (Students)	10,000 to 1	14.7 to 1	——
No fertilizers	4.12	0.813	4.76±.08

Another difference in favor of nitrate of soda as regards spring growth was the markedly greater diameter spurs on trees receiving nitrate of soda in the spring, compared to other treatments. This greater diameter accompanying greater length of spur might not be expected under normal growth conditions, but it will be remembered that these trees were typically in a high-carbohydrate-low nitrogen con-

dition before treatment, and hence the available nitrogen of spring nitrate probably favored utilization of the accumulated carbohydrates so that conditions for both an increase in diameter and length of spurs were unusually favorable.

Comparing fall nitrated trees (10 pounds per tree) with fall sulphated trees (7½ pounds per tree) the differences are not so marked for nitrate of soda shows only 9½ per cent greater spur growth.

Apparently in considering spur growth alone, 15 pounds of ammonium sulphate in the spring were equal to 10 pounds of nitrate of soda in the spring. This difference in spur growth is probably correlated with a difference in availability of the 2 materials. Spur growth is completed shortly after blossoming and hence the use of the more available material probably would result in the greater spur growth. This same correlation is brought out by a comparison of the spur growth of fall sulphated trees compared to spring sulphated trees, the latter application giving less spur growth possibly due to insufficient time to become available to the tree. A recent bulletin from the Wisconsin Station (14) by Truog et al, shows, nearly 3 times the amount of nitrates in an acid silt loam soil from nitrate of soda compared to ammonium sulphate 26 days after a June 13 application of these materials; both materials however, showed an increase in nitrates over a check plot. Observations in 1922 in another experiment with poorly growing Stayman Winesap trees in sandy loam, showed practically no increased spur growth the first year, where ammonium sulphate was applied in the spring, whereas nitrate of soda, in equivalent amounts showed marked increase in spur growth over the check trees.

Chemical analyses, presented later, actually show less nitrogen in the spurs of trees receiving spring sulphate as compared to fall sulphate, spring nitrate or fall nitrate.

It is interesting to note, however, that fall nitrate resulted in about the same terminal growth and trunk increment as spring nitrate, and about the same relation held true for fall sulphate compared to spring sulphate. Also it will be seen in Table I that doubling the amount of fertilizer resulted in greater growth response, but not in proportion to the increased application.

In brief, it appears that these weakly growing apple trees, lacking in nitrogen supply, responded more quickly and with consequently greater growth to nitrate of soda than to ammonium sulphate, probably due to the immediate availability of the former material. (The Wisconsin evidence (14) previously cited tends to confirm this suggestion.) It is possible that under soil conditions favoring rapid nitrification that such differences in response would not be apparent. However, in Maryland, observations in the several fertilizer experiments carried on during the past 4 years, in orchards responding noticeably to nitrogen, all show at this time that where the usual amounts of nitrate of soda necessary for satisfactory growth are used, a greater growth response occurs than where equivalent amounts of ammonium sulphate are used. When excessive amounts of these

TABLE II—PERCENTAGE OF TOTAL NITROGEN IN YORK IMPERIAL APPLE SPURS AFTER APPLICATION OF DIFFERENT NITROGEN FERTILIZERS. DRY WEIGHT BASIS

Treatment	Blossoming spurs April 20, 1925			Fruiting spurs June 27, 1925			Non-fruiting spurs June 27, 1925		
	Blossoms plus new growth	One year wood	Old wood	New growth	One year wood	Old wood	New growth	One year wood	Old wood
Nitrate of soda—fall	3.24	1.28	0.857	1.21	0.826	0.563	0.939	0.731	0.676
Ammonium sulphate—fall	3.00	1.06	0.742	1.034	0.693	0.518	0.852	0.764	0.590
Nitrate of soda—spring	3.12	1.13	0.637	1.46	0.816	0.563	0.917	0.783	0.710
Ammonium sulphate—spring	2.77	0.841	0.732	1.20	0.746	0.503	0.884	0.726	0.515
No fertilizer—sod	2.85	1.07	0.805	0.878	0.707	0.488	0.777	0.432	0.496

materials per tree are used or where the need for nitrogen is not so great these growth differences are often quite small.

Results of Chemical Analyses

The data in Table II present the results of nitrogen analyses of blossoming apple spurs at the "pink" stage, April 20, and of fruiting and non-fruiting spurs at the time of fruit bud differentiation, June 27. It was felt that analyses at these 2 critical periods would be most apt to give significant data. Growth of the spur and fruit setting are associated with the first period, while fruit bud differentiation and the near completion of terminal growth occur at the latter period.

Reference to Table II shows consistent differences in the nitrogen content of the spurs in favor of nitrate of soda applications compared to ammonium sulphate which agrees with the comparison of growth responses and foliage color previously detailed. Apparently the nitrogen of the nitrate of soda was taken up in greater amount than the nitrogen of the ammonium sulphate which is in accord with the possible difference in availability of these materials. On June 27 the spurs on all the fertilizer plots showed a greater nitrogen content than spurs from the check plot which again is in accordance with growth responses compared to the check. Hooker (7) and (8) has found a similar increase in content in spurs on May 22, 6 weeks after the application of nitrogenous fertilizers. Roberts (13) also has shown an increased nitrogen content of "nitrogen-starved" apple trees when placed in a high nitrogen medium.

The data in Table II show that an application of nitrate of soda made 3 weeks before blossoming (as recommended to orchardists) actually does modify the nitrogen content of the blossoms plus new growth. A glance at Table III shows the high content of nitrogen in the blossoms, plus new growth, and especially the high percentage of soluble nitrogen, which has been considered the more active portion of the total nitrogen. This increase of nitrogen in the blossom plus the new growth assumes greater importance when it is realized that the blossom plus the new growth at the "pink stage" contains over 60 per cent of the total nitrogen of an 8 to 10 year old York Imperial spur (calculated from the studies above). If the nitrogen content of the leaves had been included with that of the blossom and new growth, a still greater proportion of the nitrogen of the total spur would probably be found in the new growth (leaves, wood and blossoms). Thus an increase in the nitrogen of the new growth following a spring nitrate application might easily be correlated with the increased set of fruit and increased growth usually following spring nitrating.

Another correlation found in this work is presented in Table III. Reference to this table shows a fairly close correlation between the soluble nitrogen of the blossoms plus new growth and the spur growth attained in 1925. The spring nitrated spurs show the greatest percentage of soluble nitrogen together with the greatest spur growth in 1925. Thus an application of nitrate of soda in the spring not only increases the nitrogen content of the blossom plus new growth, but

modifies the nitrogen content with a subsequent effect on the spur growth. Therefore, the above data, where nitrate of soda was used might furnish evidence for the recommended, but largely empirical formula "apply nitrate of soda 2 or 3 weeks before blossoming."

It is rather difficult to explain why the total and soluble nitrogen of the spurs of the spring sulphated trees at blossoming time is lower than that of the check trees in sod. A possible explanation has been suggested by Truog et al (14), "High amounts of potash salts or ammonium sulphate on acid soils liberate so much soluble acidity, that nitrification and other bacterial activity is hindered." The applications of 7½ to 15 pounds of ammonium sulphate on the ground under the spread of the limbs, as used in this experiment would make quite a large application based on an acre basis.

TABLE III—Showing the Nitrogen Content of York Imperial Blossoms Plus New Growth at "Pink Stage" Following Fall and Spring Applications of Nitrate of Soda and Ammonium Sulphate

Subsequent spur growth is also shown*

Treatment	Per cent total nitrogen	Per cent insoluble nitrogen	Per cent soluble nitrogen	Spur growth in mm. 1925
10 pounds nitrate of soda—spring, 1925	3.12	2.11	1.01	11.85±.31
10 pounds nitrate of soda—fall, 1924	3.24	2.42	0.82	9.84±.17
7.5 pounds ammonium sulphate—fall, 1924	3.00	2.36	0.64	8.98±.15
7.5 pounds ammonium sulphate—spring, 1925	2.77	2.54	0.23	7.30±.12
Check in sod	2.85	2.32	0.53	4.76±.08
Check in cultivation	2.92	2.21	0.71	8.64±.14

*Percentages on a dry weight basis.

The increased spur growth where ammonium sulphate was used suggests however that a portion of the ammonium sulphate became available shortly after the "pink" stage although not early enough to influence spur growth as markedly as an application of sodium nitrate. It is possible that if some samples of spurs had been taken a few days after the pink stage, perhaps at full bloom, the nitrogen content of the spurs of spring sulphated trees would have been greater than the nitrogen content of the check trees.

The data given in Table IV of new growth of fruiting and non-fruiting spurs on June 27 show some definite nitrogen differences ascribable to previous treatments. If analyses of fruit and leaves had been made, the differences possibly would have been magnified. All treated trees have a higher soluble nitrogen content in the spurs than the check trees. The high soluble nitrogen content of the fruiting spurs of spring nitrated trees is just as marked as it was at blossoming time. However, it will be seen that the total nitrogen and soluble nitrogen of the spurs of the spring sulphated trees are relatively high, indicating that the sulphate became available at least in part.

TABLE IV—SHOWING THE NITROGEN CONTENT OF THE NEW GROWTH OF FRUITING AND NON-FRUITING YORK IMPERIAL SPURS, JUNE 27, 1925, FOLLOWING VARIOUS APPLICATIONS OF NITROGEN FERTILIZERS*

Treatment	Fruiting spurs			Non-fruiting spurs		
	Total nitrogen	Insoluble nitrogen	Soluble nitrogen	Total nitrogen	Insoluble nitrogen	Soluble nitrogen
10 pounds nitrate of soda—spring, 1925	1.46	1.037	0.423	.0917	0.787	0.130
10 pounds nitrate of soda—fall, 1924	1.21	0.982	0.228	0.939	0.808	0.131
7.5 pounds ammonium sulphate—fall, 1924	1.034	0.840	0.194	0.852	0.765	0.087
7.5 pounds ammonium sulphate—spring, 1925	1.20	0.910	0.290	0.884	0.747	0.137
Check in sod	0.878	0.775	0.103	0.777	0.701	0.076

*Percentage on a dry weight basis.

It will be noted that the new growth of the fruiting spurs contains a higher percentage of total nitrogen and soluble nitrogen than non-fruiting spurs. Hooker (5) and Harley (3) also report that fruiting spurs have a greater percentage of total nitrogen than non-fruiting spurs at approximately the same period. (About the end of June.)

General Discussion

The results of the above investigation indicate that bearing apple trees which are growing poorly from lack of a nitrogen supply, will respond with increased foliage color, terminal growth, spur growth and trunk circumference, from applications of either nitrate of soda or ammonium sulphate but a decided difference in favor of nitrate of soda at least in the first season may be expected. This difference in response will probably be less marked when excessive amounts of materials are used, or when both materials are applied in late summer or early fall.

It is possible that these differences noted in Maryland would not occur in certain sections where climatic and soil conditions would favor the utilization of ammonium sulphate.

Nitrogen studies of the spurs show that the influence of treatments on the nitrogen content of the spurs is closely related to the influence on growth response, especially since a close correlation was found between the soluble nitrogen of the spur at blossoming time and the growth attained by the spur.

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The Relation of Growth to Fruitfulness in Some Varieties of Apple

By M. J. Dorsey, *University of Illinois, Urbana, Ill.*, and
H. E. Knowlton, *University of West Virginia, Morgantown, W. Va.*

WITH bearing apple trees increased growth is generally accompanied by increased fruitfulness. Partridge ('19) and Shaw('24) have shown the relationship that exists between increase in trunk circumference and yield. Maney and Plagge ('21) working with Northwestern Greening and Jonathan found a marked correlation between both terminal twig growth and trunk circumference, and fruitfulness. Bradford ('24) found that increased growth had resulted in more abundant spur formation and more fruit buds. The results in fertilizer tests in the West Virginia experiments show this same general trend.

In view of this relation between growth and fruitfulness, it is not surprising that this relation should hold for the individual spurs of a tree. Heinicke ('17) has stressed the importance of spur growth in fruit setting. Yeager ('16) has noted that with spurs of the same age there was a marked correlation between their length and production. Roberts ('20) found a marked relation existing between spur growth and fruitfulness. He divided fruit spurs into 4 groups based upon their length and showed in general that there was a marked correlation between growth and performance.

While the length of the spurs depends upon both the variety and season, the relative length in general appears to hold for Wealthy, Oldenburg, McIntosh, Fameuse, Yellow Transparent, Northwestern Greening, Jonathan, York Imperial and Winesap. Auchter and Schrader ('23) have found that these correlations hold with many of the annual bearing varieties and with many of the biennial bearing

varieties when they are in certain types of an annual bearing condition. They found no correlation, however, between individual spur length and fruitfulness when the biennial bearing tree was in an "off" or an "on" year, except that the blossoming spurs which set in the crop year have generally made greater growth the previous year. More recently, Hooker ('25) has reported similar relationships with York Imperial. Chandler also notes in Baldwin, one of the most pronounced biennial bearers, that sometimes the bloom and the crop will be mainly on terminal twigs, the larger number of spurs being without bloom both during the crop and the succeeding year.

In analyzing the responses of trees to nitrogenous fertilizers in the West Virginia experiments, attention was given to (1) the growth of the spurs of different varieties, (2) the effect of nitrate applications on spur growth, and (3) the relation of the length of the blooming spur to the setting of fruit. In this an attempt was made to use the spur response as one of the measures of the effect of fertilizers in the experimental plots much the same as has been done with trunk circumference, yield and twig growth.

These studies were carried on in the orchard fertilizer plots at St. Mary's and Sleepy Creek, and embrace 4 varieties, Rome Beauty, Grimes, Ben Davis and York Imperial. The trees, generally speaking, were in the annual bearing condition, but have not overborne. The soil in the plot with Grimes, Ben Davis and York Imperial is shallow, deficient generally in humus, and is inclined to extremes in moisture supply. During the time these measurements were being taken, the production has been seriously interfered with by spring frosts. These considerations should be kept in mind in studying the results. The number of "spurs" or growths upon which records were taken are given in Table I. Since growths longer than 3 inches were encountered, the provisional length limit of 3 inches or so for spurs was not adhered to. It will be seen that the number of spurs measured in each variety is relatively large. It would appear, therefore, that the different curves or tables could be considered as representing fairly accurately the condition of the trees under study.

Methods: The method of taking data was as follows: Representative branches were tagged on trees at bloom under the different fertilizer treatments. The elongation that each growing point (exclusive of lateral buds) on a limb underwent the previous year was measured, recorded, and a note made as to number of flowers borne, if any. On York Imperial, Ben Davis, Grimes (Sleepy Creek experiment), and Rome Beauty (Rome Beauty experiment) at Sleepy Creek, 210 measurements were taken, on from 3 to 5 branches selected carefully as being typical for each tree. On the Rome Beauty at St. Mary's (St. Mary's experiment) about 400 growing points on each tree were measured in 1922 and 1923, and 200 in 1924. No distinction was made as noted between "spur" and "terminal" growing points except on the basis of length. In 1923, after both the first and second "drops," the same labeled branches were visited, the fruiting growths measured, and the number of fruits which had set on

TABLE I—NUMBER OF GROWING POINTS INCLUDED IN THE GROWTH-PERFORMANCE STUDY

Year	St Mary's, W. Va.		Sleepy Creek, W. Va.							
	Rome (31 years old)		Rome Beauty (13 years old)		Grimes (20 years old)		York Imperial (20 years old)		Ben Davis (20 years old)	
	Nitrated	Not nitrated	Nitrated	Not nitrated	Nitrated	Not nitrated	Nitrated	Not nitrated	Nitrated	Not nitrated
1922	13401	7164	2916	4132	3150	6302	2520	3780	4200	5670
1923	7570	4058	2425	4341	2520	3780	2520	3780	2520	3780
1924	8874	3442	3967	3767	2618	3708	2515	3775	2520	3795
Total	29845	14664	9298	12240	8288	13790	7555	11335	9240	13245

each was recorded. In 1924, the first set only was taken after the first drop. The set was recorded only after the first drop at Sleepy Creek in 1923 and 1924. In 1922, frosts at bloom killed practically all blossoms in both experiments.

Spur Length and Bloom: The data from the fertilizer plots at Sleepy Creek are presented in Tables II and III. On account of the fact that the trees are very irregular in bearing in this plot (Dorsey and Knowlton '24), and also because there have been significant differences in the spurs as a result of the treatments in only a few of the trees, the data for the nitrated and non-nitrated plots have been combined. This gives an analysis of the spur behavior for the different varieties on a broad scale which it would seem would be quite dependable for the conditions involved.

TABLE II—PER CENT OF SPURS OF DIFFERENT LENGTHS BLOOMING ON GRIMES, YORK IMPERIAL, BEN DAVIS AND ROME BEAUTY AT SLEEPY CREEK

Year	Variety	Length of growth (inches)						Per cent total bloom
		0–.12	.12–.25	.25–.50	.50–1	1–6	6–	
1922	Grimes	14	36	46	39	28	13	26
1923	"	8	41	47	50	35	22	27
1924	"	8	27	29	21	13	4	13
1922	York Imperial	14	41	44	34	30	17	23
1923	" "	19	51	63	51	34	35	41
1924	" "	5	9	11	5	5	0	6*
1922	Ben Davis	15	30	48	10	54	56	34
1923	" "	14	36	49	49	58	75	41
1924	" "	5	24	28	28	17	5	13
1922	Rome Beauty*	8	24	41	24	27	17	21
1923	" "	44	59	70	66	80	72	65
1924**	" "	16	56	43	46	59	60	48

*Thirteen year old trees.
**Nitrated plots only.

TABLE III—PER CENT OF BLOOMING SPURS OF DIFFERENT LENGTHS SETTING AT LEAST ONE FRUIT IN THE VARIETIES UNDER STUDY AT SLEEPY CREEK

Year	Variety	Length of growth (inches)						Per cent of blooming spurs to set
		0–.12	.12–.25	.25–.50	.50–1	1–6	6–	
1923	Grimes	32	42	46	25	55	67	42
1924	"	14	77	61	80	60	25	55
1923	York Imperial	42	28	20	10	36	54	26
1924	" "	22	47	90	77	13	—	37
1923	Ben Davis	24	40	58	48	63	86	56
1924	" "	6	41	17	49	47	92	34
1923	Rome Beauty*	10	16	26	21	25	31	23
1924**	" "	3	95	50	36	42	49	38

*Thirteen year old trees.
**Nitrated plots only.

Table II shows the per cent of spurs in each length class for each variety that bloomed in 1922, 1923 and 1924. It will be seen that a relatively small per cent of spurs of the one-eighth inch class bloomed in all varieties. This per cent of bloom increased in the next 2

growth classes. In the classes which made above an inch in growth the per cent of bloom tended to fall off with Grimes and York Imperial and remain stationary, or even increase, with Ben Davis and Rome Beauty, the 2 terminal bearing varieties. The set is surprisingly large in the one-eighth inch class in view of the relatively small number of spurs of this length to bloom. There is also a marked drop in the number of this length to set in each of the varieties following the crop of 1923.

The behavior of Rome Beauty (30 year old trees) at St. Mary's is similar (Figures 1-3) to those at Sleepy Creek. In 1924 (Figure 3), however, the curve is downward. The apple crop was large in 1923. There was also a severe scab infection and growth was markedly less, resulting in a light bloom in 1924 and a tendency of the growths to behave like spur bearing varieties in an "off" year. The results, in general, agree with our previous knowledge of the bearing habits of these varieties, i. e., Grimes and York Imperial bear on "spurs" and Ben Davis and Rome Beauty bear on "terminals."

Nitrate applications in the Rome Beauty experiment at St. Mary's have markedly increased bloom over the checks on the shorter length classes (one-fourth inch and above), but not on the longer length classes (6 inches and above), since the curves for per cent of bloom tend to coincide in Figures 1-3 for each year. This would indicate that nitrogen was less of a limiting factor in the long vigorous spurs than in the short ones. With nitrogen applications also (6 pounds per tree), the one-eighth inch class also shows a considerably increased bloom over the checks.

Spur Growth and set: The relation of length of previous season's growth to set of fruit is presented in Table II for the experiments at Sleepy Creek and Figure 4 for the Rome Beauty experiment at St. Mary's. Spurs making one-eighth of an inch growth the previous season had a relatively low percentage of set. York Imperial seemed to set better on this length of spur than did the other varieties. With Rome Beauty and Ben Davis higher percentages of set are shown with increasing lengths of previous season's growth. While the data for York Imperial and Grimes are inconclusive, there seems to be a tendency toward an increasing percentage of set with an increase in the previous season's growth. With Rome Beauty at St. Mary's (Figure 4) nitrate applications have markedly increased set, particularly on the shorter growth classes. As with bloom there was a tendency for the curves to coincide on the longer growth lengths.

A study of Figure 5 will show how nitrate applications have influenced growth in Rome Beauty in the St. Mary's experiment. The curves based on growth show that the nitrate applications have modified the distribution of the spur population. The percentage of spurs in the one-eighth inch class has been reduced one half. The growths of Rome Beauty in the one-eighth inch class bloomed and set lightly in this experiment. Percentages of spurs in the longer growths which both bloom and set (one inch and above), have been markedly increased.

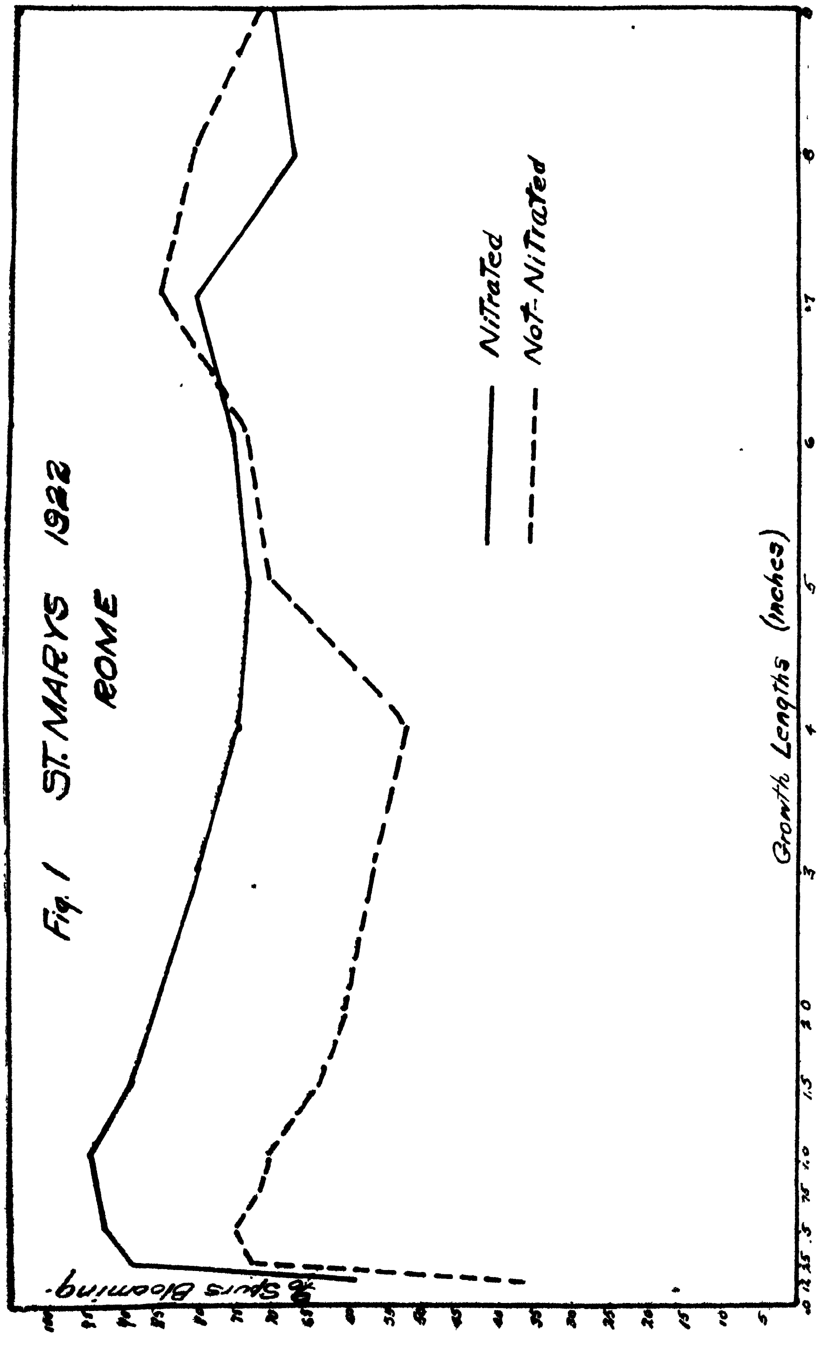
Fig. 1 ST. MARYS 1922
ROME
Nitrated
Not-Nitrated
Growth Lengths (inches)
% Spurs Blooming.

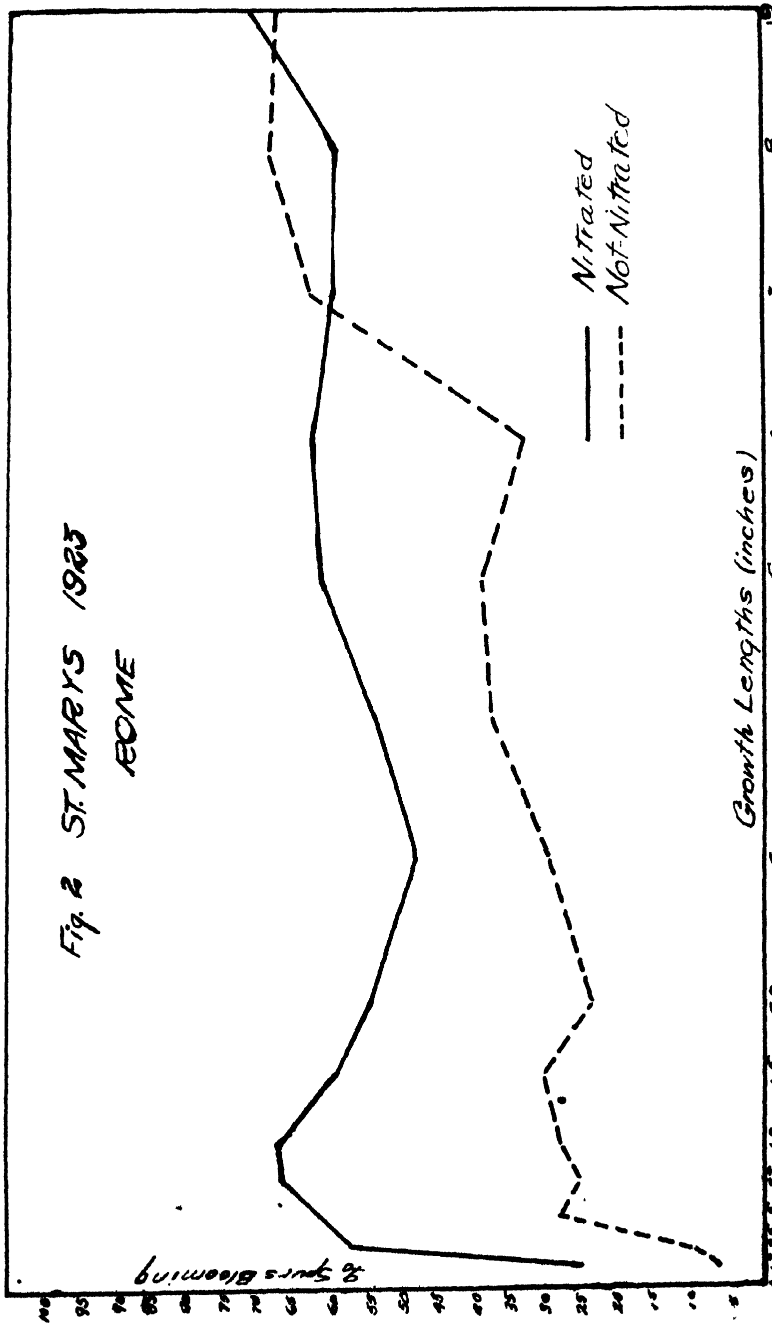
Fig. 2 ST. MARYS 1925
ROME
Nitrated
Not-Nitrated
Growth Lengths (inches)
% Spurs Blooming

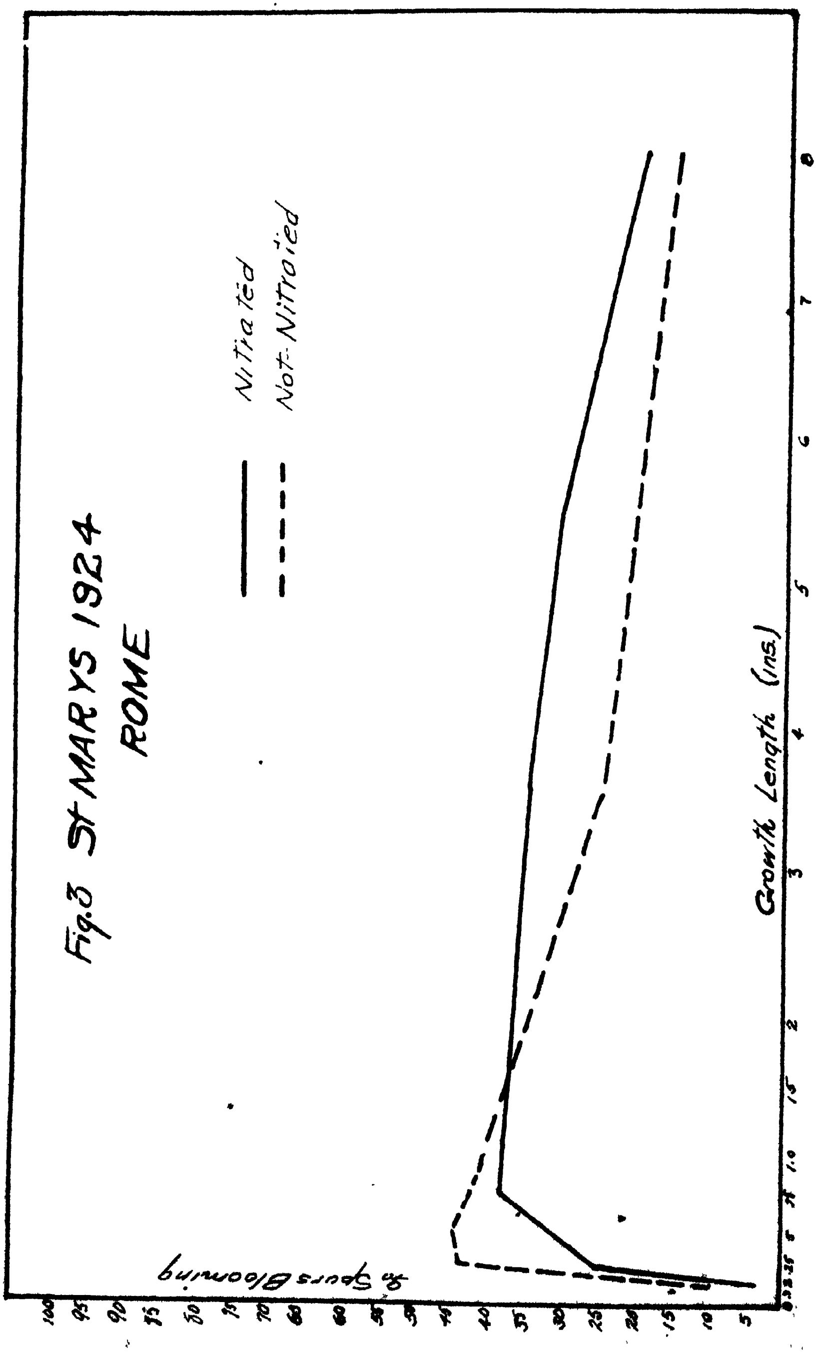
Fig.3 St MARYS 1924
ROME
Nitrated
Not-Nitrated
Growth Length (ins.)
% Spurs Blooming

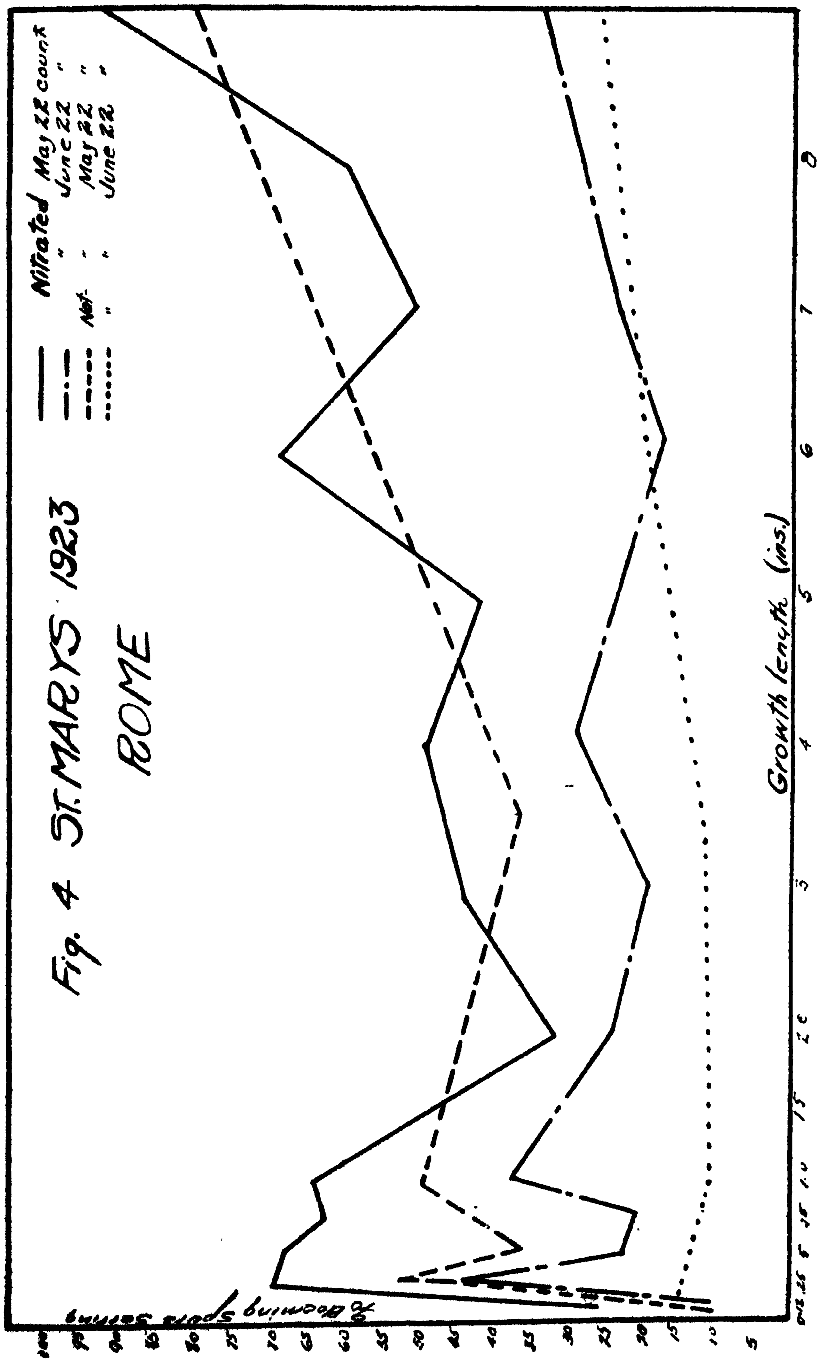
Fig. 4 St. MARYS 1923
ROME
Nitrated May 22 count
" June 22 "
Not- May 22 "
" June 22 "
Growth length (ins.)
% Blooming Spurs Setting

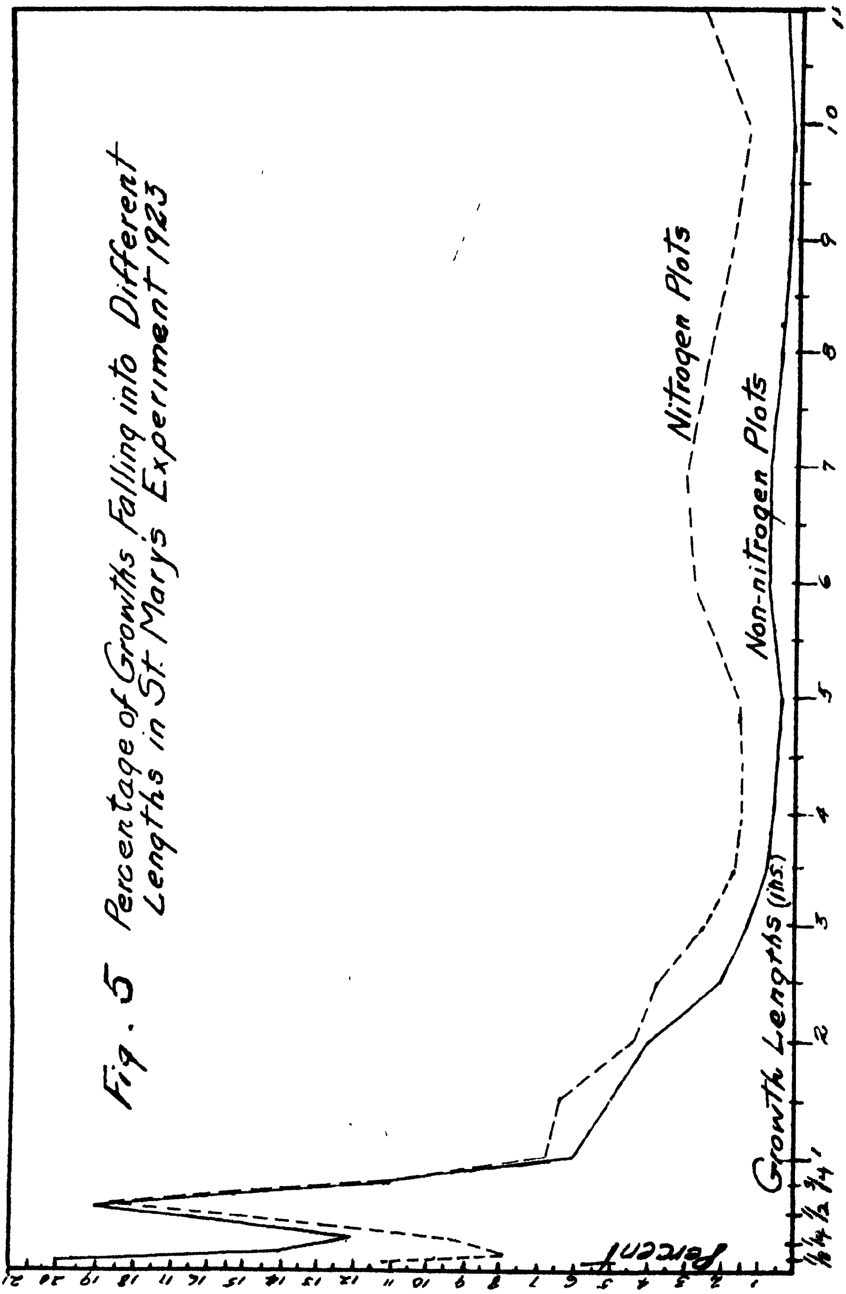

Fig. 5 Percentage of Growths Falling into Different Lengths in St. Mary's Experiment 1923

The results from these studies with annually bearing York Imperial and Grimes corroborate in a general way those of Roberts ('20) in that spurs tend to group themselves into classes based on their length and performance. With Ben Davis and Rome Beauty, however, increased spur growth was accompanied by increased fruitfulness. Hooker and Bradford ('21) reported similar relations with Gano, Jonathan, and Wealthy. Theoretically, there must be a limit to this, but it had not been reached by the trees growing under the conditions of these experiments.

The curves for set follow, in a general way, those for bloom. This does not necessarily mean that similar nutritional conditions are necessary for both fruit bud development and fruit setting. If fruit buds are to form certain proportions of carbohydrates, nitrogenous compounds appear necessary. Undoubtedly, a certain excess of available carbohydrates is the controlling factor on vigorous spurs, while on weak ones a deficiency of nitrogen is preventing fruit bud initiation, or possibly limiting their normal development.

Vigorous spurs "set" in greater numbers than weak ones, probably because of their larger supply of stored food and because of their greater ability to compete for water and nitrogen. Possibly they are able to do this because of larger conducting tissue and because of their greater "demand" (Breazeale '23) for these essential substances.

Neither bloom nor set on the longer spurs of Rome Beauty in the St. Mary's experiment have been increased by nitrate applications. This would indicate that a sufficient supply of nitrogen was present in them whether on nitrated or non-nitrated trees. On the shorter spurs, however, marked increases in both bloom and set occurred.

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Some Studies on the Fruiting Habit of the York Imperial Apple

By M. J. Dorsey, *University of Illinois,* Urbana, Ill.*

THE studies of the fruiting habit of York Imperial reported here were begun in the spring of 1923 in the Thatcher orchard near Martinsburg, Berkley County, West Virginia. The following spring additional studies were initiated in the Sleepy Creek orchard of the American Fruit Growers in Morgan County and in the Arcadia orchard near Falling Waters, also in Berkley County. These orchards were chosen because they presented various conditions of the tree for this variety.

The trees in the Thatcher orchard were 27 years old in 1923. This orchard has been one of the most productive in the region—a condition which can be attributed to the cultivation and the cover crops turned under. By 1923, however, many trees were in a typical biennial condition and in others different limbs were alternating. While considerable pruning had been practiced, nevertheless, the larger limbs tended to be much too thick on most trees. Locust injury, tree borers, heavy production, and a letting up somewhat on the cultivation during the war had all contributed to a lowering of the generally excellent condition of this orchard. As a result of soil variation and slope of the land, trees could be selected in many different degrees of vigor.

The trees in the Sleepy Creek orchard were about 20 years old in 1924 when the special treatments were started on trees adjacent to the plots of the Sleepy Creek experiment. This orchard has been cultivated each year and recently a cover crop, generally of rye, has been turned under. The soil is a shallow Holston loam with a shale subsoil and is generally low in humus. The trees appear to suffer during the latter part of some seasons from drouth. The pruning has

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These studies were made while the writer was connected with the West Virginia Agricultural Experiment Station. The following students assisted in taking the measurements or working up the data: R. C. McDonald, H. P. Sevy, Lewis Stark, J. W. Prettyman and O. J. Beard. Acknowledgment is made here of their assistance in making this work possible. Appreciation of the cooperation and assistance given by Mr. Stanley Fulton of the American Fruit Growers, Mr. Harlan Thatcher, and Mr. Beall, Superintendent of the Arcadia Orchard, is also recorded here.

been moderate in severity and of a type to open up the top and let in the light. The trees chosen for study generally had a scant bloom and produced a light crop. The general condition might be described as one of low production with probably both nitrogen and moisture as limiting factors.

The age of the Arcadia orchard is about the same as the Thatcher orchard and the trees are about the same size. The trees selected were in the typical biennial habit of bearing and this general condition prevailed over most of the 80 or so acres planted to this variety. The soil was a clay loam relatively low in humus. The tree tops were thick and in need of pruning, although the general appearance of the orchard at a distance was good. The yellowish green foliage in late summer indicated that there was a nitrogen deficiency generally in this orchard.

It will be seen that these trees present some of the more common conditions encountered in this variety. On account of the rather erratic bearing brought about by the tree condition and also by unfavorable weather, it became necessary to devise some method of measuring the status of growth and bloom before the treatments were begun as well as afterward. Accordingly, the following methods were adopted.

Methods: In the spring of 1925 in order to measure the effect of the experimental treatments initiated in 1923 and 1924, a history was made of the behavior of spurs and terminals both previous to and after the treatments. This study was made at the pink stage of bloom in 1925 and included a record of both bloom and growth for either a 3 or 4 year period.

In taking the bloom and growth records the procedure was as follows: The first record made was whether or not the growth bore flowers in 1925. Next the length of the 1924 growth was measured and a record was made as to the presence or absence of a bloom scar on that year's growth. This process was repeated back through the third or fourth annual growths from the growing point. In this way the length of growth for any year, or the bloom record, for the entire spur or shoot population of 300 or so could be determined. While only the length of the different growths was measured it was recognized that both thickness and length are correlated with performance. The data were taken in this way so that it would be possible to compare the performance of the population one year either as to growth or bloom, with that of another, rather than to study spur performance as such. This seemed necessary because of the uncertainty of yield as a record of tree response.

The type of pruning given the experimental trees was fairly uniform throughout. In some of the thicker limbs the detailed cutting removed about one-half of the growing points. On other limbs the pruning was lighter. The aim was to leave the different tops as uniform as possible rather than to remove a given amount of wood. The "water sprout" growth was relatively light following the pruning.

The mulch put on in 1923 on trees 13–15 in row 13 in the Thatcher

orchard, was straw, and was applied about 6 to 8 inches deep out to the spread of the branches. It was not renewed in 1924. Corn fodder mulch put on tree 13 in row 14 was of about the same thickness and spread. The feeding roots came up the first summer in the moist surface layer under the mulch and this may account in part for the extra growth the first season.

The nitrate applications were made broadcast before bloom and the amounts applied in the different orchards are indicated in the tables.

The biennial bearing habit. The biennial bearing habit of York Imperial occurs in young trees as well as in older ones. This tendency is so pronounced in some orchards that it is not overcome completely by even the loss of a crop at bloom from frosts. It should not be inferred, however, that York Imperial is the only variety to alternate because under some conditions Ben Davis shows the same tendency.

In York Imperial some secondary effects of heavy production tend to favor alternate bearing. The first heavy crops bend the limbs downward and the drooping position becomes permanent with successive crops. As a result of this there is a checking of the first terminals of the pre-bearing age and a replacement of them by some of the upper laterals which in turn become the true terminals. When this process is repeated and the bending is increased with successive crops as many as 4 or 5 suppressed terminals can be found on some of the larger main limbs of older trees. This drooping tendency in time results in a shading and crowding process with the under smaller limbs which in time become weakened from shading, and with further suppression and crowding, die. Unless the pruning given the trees corrects this tendency, the small poorly colored fruit and the thick brushy top become typical corollaries of the off year.

In the recovery from the first period of heavy production York Imperial often sends out a vigorous upright growth from the "elbows" of the drooping limbs which forms a second story to the tree. The resultant tree of this process undisturbed is characterized by great extremes in the relative vigor of the different limbs and by a great range in the size of the fruit with the bulk of the crop in the smaller sizes (see trees 10-3 and 4 in the Arcadia orchard in Table VII). The main limbs in most of the trees in both the Thatcher and Arcadia orchards had undergone this transition in spite of the fact that more pruning than usual had been done. The bending process, therefore, appears to be an important factor in bringing about a weakened condition of a considerable proportion of the spurs of a tree because of the shading and crowding of the under and inner branches.

In order to study the individuality of the different main limbs of the tree in the spring of 1923, the main limbs on 27 trees selected as being typical of the Thatcher orchard were marked as to whether or not they were blooming. On the average 5.3 limbs per tree, or a total of 195 limbs, were included in the studies. In 1923, 153 of these were off and 45 bloomed; in 1924, 57 were off and 142 bloomed; and in 1925, 122 were off and 82 bloomed. Twenty of the 195 limbs

missed blooming 2 years in succession and 2 were off for 3 years. Thirty-five bloomed 2 years in succession and 2 were recorded as blooming each of the 3 years. This condition is typical of many old York Imperial trees even when given fairly good care. It appears, however, that the cultural program beginning with 1923, of nitrating (9 pounds per tree), pruning, and cultivating was making some headway in correcting the alternation of the limbs. These trees were growing in the strongest soil in the orchard as can be seen by comparing the bloom on the trees in row 7 in Table 1 with some of the other trees in the Thatcher orchard.

In older trees the individuality of the different main limbs in York Imperial becomes more pronounced especially if a number of the lower limbs are cut off to make cultivation easier, as had been done in the Thatcher orchard. While the different limbs are united in the trunk and can be considered as integral parts of the tree, in reality they are quite distinct as shown by the ribbing on the trunk. The limb connections can generally be followed down the trunk through the ribs or ridges to the root connections This situation enables each main limb to respond as a unit, more or less independently of the rest of the tree– a condition which underlies the alternation of limbs in the Thatcher orchard.

At Sleepy Creek still another condition of York Imperial is found with younger and less productive trees. These trees are characterized by their slow growth recently Tree 16-3 was selected as representative of an extreme instance of slow terminal and spur growth of this variety. Of 5 limbs studied in detail the spurs had not bloomed until on the sixth annual growth from the terminal on 3 limbs and not until the seventh in 2 limbs. There had been 1079 annual growths on all the spurs borne on these limbs and of this total number of opportunities to bloom there were only 119 bloom scars to be found. The terminals of such limbs were making a very slow growth and had much the same appearance as spurs on the older wood.

Trees 15–3 and 15–4 had much the same general appearance as 16–3. At a glance it would appear that there were more than twice as many growing points as there should be. Accordingly in order to study the response of these 2 trees, one-half of the spurs and limbs were removed. When the growths removed were gathered and classified the following numbers of each length were found to have been taken from 15–3: spurs under 3 inches, 3200; limbs in the 6 inch class, 657; in the 12 inch class, 573; 2 feet long, 220; and between 3 and 4 feet, 60. The laterals were not taken from the longer growths and hence all shorter growths are more numerous than these numbers indicate. For the same classes the growths removed from 15–4 were as follows: 3 inches, 3000; 6 inches, 440; 12 inches, 284; 2 feet, 64; and between 3 and 4 feet, 43. Something of the condition of the spurs removed can be seen from the following: Five hundred spurs from tree 15–3 bloomed 637 times in 2759 annual growths, or an averaged 4.3 growths per bloom. On tree 15–4 an equal number bloomed 751 times, or 3.7 growths per bloom. The average annual

TABLE I—Bloom Records of Selected Trees in the Thatcher, Sleepy Creek and Arcadia Orchards. York Imperial

	Tree	Treatment				Number of spurs in 300 blooming			
		Pruned	Nitrated	Mulched	Cultivated	1922	1923	1924	1925
Thatcher Orchard	5–2	detailed	9 pounds	none	cultivated	18	263	3	255
	5–2	none	" "	"	"	15	281	0	240
	7–8	detailed	" "	"	"	201	26	80	142
	7–8	none	" "	"	"	104	56	57	140
	7–9	detailed	" "	"	"	62	25	101	54
	7–10	none	" "	"	"	96	23	168	18
	7–10	detailed	" "	"	"	54	33	39	46
	7–11	"	" "	"	"	146	58	89	46
	7–11	none	" "	"	"	148	53	112	50
	7–12	"	" "	"	"	140	37	109	92
	7–12	detailed	" "	"	"	82	75	99	144
	13–13	"	" "	1923 straw	"	62	127	29	223
	13–14	"	" "	"	"	212	49	259	2
	13–14	none	" "	"	"	248	32	278	0
	13–15	"	" "	"	"	144	57	154	120
	13–16	detailed	" "	none	"	110	67	60	192
	13–18	none	" "	"	"	29	176	23	270
	14–13	"	" "	1924 corn fodder	"	158	85	84	214
	14–15	detailed	" "	none	"	63	108	39	229
	14–16	none	" "	"	"	87	126	72	210
	14–18	detailed	" "	"	"	90	109	86	211
Arcadia Orchard	8–4	none	8 pounds	none	disked	—	191	2	222
	9–3	detailed	" "	"	"	—	182	9	187
	9–4	"	" "	"	"	—	106	1	116
	9–5	"	" "	"	"	—	136	7	185
	9–6	"	" "	"	"	—	114	5	129
	10–6	none	none	"	"	—	163	13	86
Sleepy Creek	15–1	detailed	6 pounds	none	cultivated	—	35	1	112
	15–2	"	" "	"	"	—	54	49	157
	15–3	" spec.	none	"	"	—	12	16	77
	15–4	" "	6 pounds	"	"	—	122	31	166
	16–1	none	4 "	"	"	—	.15	63	38
	16–2	"	" "	"	"	—	30	11	168
	16–3	heading back	" "	"	"	—	16	0	128
	16–4	" "	" "	"	"	—	1	2	99

spur growth was .29 of an inch on tree 15–3 and .34 on 15–4. The response of these 2 trees in growth, to the unusually dry midsummer of 1924 can be seen in Table VI. The 2 trees were pruned practically the same except that the limbs of 15–3 were headed back to a pencil size on account of the length of the terminals. Very few water sprouts were formed following this type of pruning and the trees did not appear to be thinned out too much.

It will be seen from the foregoing that with this variety a condition of the tree may be encountered as a result of either heavy production or slow growth that is difficult for practical growers to handle. This gives a picture of the tree condition which led in 1923 to the initiation of some detailed studies into the growth and fruiting habits of York Imperial.

Some characteristics of York Imperial bloom: As noted previously in making the growth measurements on the spurs, the bloom records were also taken. The measurements were made at about the pink stage so by noting for each spur the bloom for the current season, or the bloom scars in previous growths, it was possible to determine from a random sample of 300 spurs the extent of the bloom for each of the last 3 or 4 years. The data obtained in this way for the different trees are presented in Table I.

The numbers in the 4 columns at the right indicate the proportion of 300 spurs blooming for any one of the years given. There does not appear to be a definite on and off bloom in the Thatcher orchard as in the Arcadia orchard, although some of the trees, as 5–2 or 13–14 in the former, show a marked tendency to alternate. In the Sleepy Creek orchard it will be noted that there is an unusually light bloom for both 1923 and 1924, but that for 1925 the bloom was conspicuously greater. The Arcadia orchard was typically alternating while at Sleepy Creek the bloom was generally irregular; i.e., scattered on some trees and heavy on others. The bloom records indicate very closely, therefore, the condition in each of the orchards and agree quite closely with the other more general observations. It will now be of interest to note the status of spur growth which underlies this condition of bloom.

The relative length of the blooming and non-blooming spurs: In Table II the blooming and non-blooming spurs have been separated year by year in their respective lengths for certain of the trees included in Table I. For briefness in presentation only 7 trees with different variables in the treatment have been included. This arrangement makes it possible (1) to see what length of spur may have been "off" or "on" before the treatments, and (2) to see the influence of the treatments upon both the blooming and non-blooming growths. As in Table I, 300 spurs were made the basis of comparison each year and the record deals with the same set of spurs over the 3 or a 4 year period, as the case may be.

It will be seen from a study of this table that the spurs of York Imperial as grown under these conditions are relatively short, although a surprisingly large number of longer growths may bloom.

TABLE II—THE LENGTHS IN INCHES OF THE BLOOMING AND NON-BLOOMING SPURS IN YORK IMPERIAL

Tree	Year	Blooming or not blooming	.12	.25	50	.75	1.0	1.5	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	Total
Thatcher	1921	Spurs on	21	32	4	1	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	62 } 291
13–13		Spurs off	160	50	7	3	8	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	229
Pruned	1922	" on	51	54	7	2	7	2	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	126 } 291
Mulched		" off	98	42	9	3	9	—	1	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	165
Nitrated	1923	" on	15	12	12	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	44 } 291
9 pounds		" off	133	85	11	1	4	2	5	2	2	—	1	—	—	—	—	—	1	—	—	—	—	—	—	247
Cultivated	1924	" on	42	73	23	9	21	8	17	8	9	—	8	—	3	—	—	1	1	—	—	—	—	—	—	223 } 291
		" off	5	19	4	2	6	3	10	3	6	—	3	—	4	1	—	1	—	1	—	—	—	—	—	68
Thatcher	1921	" on	48	50	7	—	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	111 } 300
13–16		" off	142	42	2	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	189
Pruned	1922	" on	35	30	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	67 } 300
Nitrated		" off	127	82	10	—	11	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	233
9 pounds	1923	" on	31	29	4	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	68 } 300
Cultivated		" off	136	78	8	—	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	232
	1924	" on	50	78	36	7	20	3	8	3	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	207 } 300
		" off	9	29	22	3	15	4	7	2	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	93
Arcadia	1922	" on	2	42	32	—	27	1	6	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	111 } 300
9–4		" off	17	96	48	—	22	—	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	189
Pruned	1923	" on	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1 } 300
Nitrated		" off	70	186	29	—	11	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	299
8 pounds	1924	" on	44	63	3	—	1	—	—	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	114 } 300
Disked		" off	32	96	24	—	18	—	2	—	4	—	5	—	4	—	1	—	—	—	—	—	—	—	—	186
Arcadia	1922	" on	63	30	20	3	9	3	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	136 } 300
9–5		" off	93	44	6	—	8	1	8	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	164
Pruned	1923	" on	1	4	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7 } 300
Nitrated		" off	177	82	14	3	13	1	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	293
8 pounds	1924	" on	104	49	4	—	11	3	1	5	3	1	3	—	1	—	—	—	—	—	—	—	—	—	—	185 } 300
Disked		" off	56	33	5	—	14	—	2	3	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	115
Arcadia	1922	" on	45	28	17	1	28	2	23	11	6	—	2	—	—	—	—	—	—	—	—	—	—	—	—	163 } 300
10–6		" off	102	12	3	—	13	1	4	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	137
Check tree	1923	" on	6	6	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	13 } 300
Disked		" off	147	89	10	2	18	5	9	6	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	287
	1924	" on	59	18	7	—	3	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	88 } 300
		" off	160	27	9	—	10	—	5	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	212
Sleepy	1922	" on	1	28	6	1	11	1	2	—	1	—	5	—	—	—	—	—	—	—	—	—	—	—	—	56 } 300
Creek 15–2		" off	107	48	11	8	24	4	17	15	4	2	4	—	—	—	—	—	—	—	—	—	—	—	—	244
Pruned	1923	" on	5	20	8	1	7	3	1	1	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	49 } 300
Nitrated		" off	100	54	12	7	31	5	17	15	6	—	3	—	1	—	—	—	—	—	—	—	—	—	—	251
6 pounds	1924	" on	19	45	12	2	18	9	12	6	7	1	3	—	4	3	1	2	3	—	2	4	3	—	2	158 } 300
Cultivated		" off	8	15	9	2	15	7	22	16	9	6	8	—	2	1	5	1	2	—	3	4	3	—	4	142
Sleepy	1922	" on	2	4	5	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	12 } 300
Creek 15–3		" off	172	81	31	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	288
Pruned	1923	" on	7	5	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	16 } 300
Cultivated		" off	162	91	27	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	284
	1924	" on	36	24	5	—	3	—	1	—	—	1	—	—	3	—	2	—	1	—	1	—	—	—	—	77 } 300
		" off	28	64	48	6	23	4	8	8	3	2	5	—	4	—	8	—	7	1	4	—	—	—	—	223
Total		on	687	725	218	27	188	35	84	35	29	4	24	1	11	3	3	3	5	—	3	4	3	—	2	2094
		off	2241	1445	359	40	293	43	128	78	39	11	30	—	15	2	14	2	10	2	7	4	3		4	4770

There appears to be no significant or consistent difference between the length of the blooming and non-blooming spurs; i. e., any length may bloom or not bloom. When the totals for the on or off condition are compared, however, the growths below one-half inch in length which do not bloom are far in excess of those which do.

The influence of the different treatments can be seen upon both spur growth and bloom. The first year following the treatments bloom was increased in some trees without a pronounced stimulation in the length of spur growth. Thickness appeared to be influenced most. This was partly due to fruit production and partly to drouth. Following the treatments, however, the tendency is for the off growths to be more vegetative. The transition is quite noticeable in 13–13, 9–4 and 15–2 and 3. The large proportion of short growths in 13–13 in 1923, which are not blooming, is a typical instance of the stimulation of weak spurs. As to just what progress these differences indicate in correcting the off year will, of course, depend largely upon the crop, season and continuance of the treatments, especially pruning, nitrating, or cultivating. The relative length of the blooming and non-blooming spurs does not appear to be greatly changed by any of the treatments used here; i. e., when growth length is increased in one it tends to be increased in the other. A possible exception to this tendency is shown in 15-3 where the special treatments induced a terminal growth which did not bloom as in 15–2, to which nitrogen was applied in addition to the other treatments. On the whole, therefore, while the shorter spur lengths—below ¾ inch—tend to fall largely in the off condition, a considerable proportion of this number do bloom, thus indicating that the general tree condition is a big factor in determining performance

The length of the spurs which set fruit: It will now be of interest to see what spur lengths retain fruit after the June drop. The data on this point are summarized in Table III for certain of the trees in the Thatcher orchard only for 1924 and 1925.

Not considering the different treatments, it will be seen that fruit may set on York Imperial on many different growth lengths. Particularly interesting is the difference in the length which set in tree 13–13 between 1924 and 1925. From Table VII, it will be seen that 504 pounds of fruit were borne that year. The next season was a light crop year generally on account of frosts, but during 1924 relatively long growths formed fruit buds on account of the exceptionally dry midsummer. The mulch no doubt was partly responsible for fruit bud development under these conditions. The fruiting lengths on the pruned and unpruned side of tree 5–2 in 1925, are also interesting. This shows the tendency of York Imperial to fruit on the short growths in the on year. In general it will be seen that more longer growths were fruiting in row 13 in 1925, than in 1924. This difference was also noticeable during the growing season because in the pruned and mulched trees the first season was characterized not by a long spur growth, but by an exceptionally "fat" growth of the short spurs. The data show that growths of different lengths may set

TABLE III—THE LENGTH OF GROWTH WHICH SETS FRUIT—YORK IMPERIAL WAS IN BLOOM MAY 1 IN 1924 AND APRIL 25 IN 1925 THE SET RECORDS WERE TAKEN JUNE 12 IN 1924 AND JUNE 22 IN 1925

Tree		Year	Length of spur or growth, inches													Total
			.12	.25	.50	.75	1.0	1.5	2	3	4	5	6	7	8	
Thatcher	13–13	1924	283	121	25	7	8	4	—	1	1	—	—	—	—	450
"	13–14	"	137	66	11	2	5	—	3	—	—	—	—	—	—	224
"	13–15	"	107	72	26	6	7	2	2	2	1	—	—	—	—	225
"	13–16	"	263	149	30	5	2	—	—	—	—	—	—	—	—	449
"	13–18	"	247	113	32	13	22	11	6	3	—	1	—	—	—	448
" pruned	5–2	1925	6	95	27	—	26	8	12	14	8	1	2	2	—	201
" unpruned	5–2	"	106	66	14	—	12	—	3	—	—	—	—	—	—	201
"	5–3	"	60	83	17	—	11	4	14	3	6	1	2	—	—	201
"	13–13	"	8	96	8	—	18	2	23	12	14	8	8	2	2	201
"	13–14	"	30	81	16	—	37	3	12	7	9	6	—	—	—	201
"	13–15	"	65	92	15	—	17	3	3	4	1	1	—	—	—	201
"	14–18	"	7	86	20	4	42	4	18	4	9	5	—	—	—	199
		Total	1319	1120	241	37	207	41	96	50	49	23	12	4	2	3201

in York Imperial as well as bloom. The relationship, therefore, between the character of the growth induced by tree condition and bloom or set, aside from mere length or thickness, appears important.

The influence of the different treatments on spur growth: One question which came up in regard to the pruning was whether the growing points which had been making the shorter growths would respond following the different treatments comparable to the more vigorous ones. In Table IV the growths for 1922 up to and including the 1 inch class, have been entered with reference to the growth made for 1923. In this way all of those spurs which grew a given length in 1922 (e. g. the .25 class) are classified according to their elongation the season following the different cultural treatments. Three hundred measurements were made on each tree, but only those above the 1 inch class have been included The number of growths not included can be determined from the grand total.

There seems to be a decided tendency for the longer growths of one year to also make the longer growth the next year. The correlation would not be high in the slower growing trees as Thatcher 5-2, but it appears higher in the faster growing trees. It should be kept in mind, however, that the influence of bearing upon spur growth cannot be determined from the way in which these data are taken. The spur growth of Arcadia 10 6 is typical for old York Imperial trees in the biennial condition; compare with the pruned side of Thatcher 5–2 which was making a similar growth before being pruned (see the totals for each class in the column to the right). If curves are drawn for the frequency distribution of each year the influence of the cultural treatments can easily be seen For instance, in tree 13–13 (Thatcher) 177 spurs grew only one-quarter of an inch in 1922, while in 1923 only 30 growths came in this class. The 177 spurs which grew only one-quarter of an inch in 1922, however, had a totally different frequency distribution in 1923. The records included in Table IV, therefore, show a general response of the shorter growths over the tree to the different treatments with a greater growth, relatively, of the longer spurs.

Using the shorter spur lengths only (.12 to .75 inclusive) as a basis for comparison, let us study the data in Table V. The proportion of these growths in a total of 300 is given for certain trees in the different orchards. In the Thatcher trees the growths of 1921 and 1922 can be compared with those of 1923 and 1924, in order to evaluate the effect of the different treatments initiated before bloom in the spring of 1923. In the other trees the 1924 growths can be compared with 1922 and 1923.

With increased growth following the different treatments there has been a decrease of the shorter growths in a random sample of 300 growing points. The proportion of these in 300 may be taken as a measure of the treatments upon growth. One thing which is noticeable is the relative stability of the spurs in the older trees, especially when they are bearing. It was much easier to stimulate growth in the younger trees in the Sleepy Creek orchard. Nitrating without prun-

TABLE IV—Showing the Growth the Different Spur Lengths of 1922, Made the Following Season of 1923, York Imperial

Tree	Growth of 1922	Growth each of the 1922 classes made in 1923																			Total	Grand Total
	23	.12	.25	.50	.75	1.0	1.5	2	3	4	5	6	7	8	9	10	11	12	13	14		
Thatcher 5-2, Pruned side, Nitrated	.12	4	6	2	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	14	
	.25	7	44	41	10	17	8	11	1	1	1	—	—	—	—	—	—	—	—	—	141	
	.50	2	17	5	6	1	4	5	—	1	—	—	—	—	—	—	—	—	—	—	41	
	.75	—	2	13	1	6	1	2	2	—	—	—	—	—	—	—	—	—	—	—	27	
	1.0	—	5	6	6	7	2	1	1	1	1	1	—	—	—	—	—	—	—	—	31	254
Thatcher 5-2, Unpruned side, Nitrated	.12	4	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7	
	.25	42	41	48	11	15	—	2	—	—	—	—	—	—	—	—	—	—	—	—	159	
	.50	3	19	10	5	3	1	1	—	—	—	—	—	—	—	—	—	—	—	—	42	
	.75	1	8	15	3	7	—	1	—	—	—	—	—	—	—	—	—	—	—	—	35	
	1.0	5	9	4	9	1	—	2	1	—	—	—	—	—	—	—	—	—	—	—	31	274
Thatcher 13-13, Nitrated '23, Mulched, Cultivated, Pruned	.12	1	4	7	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14	
	.25	—	26	58	5	34	8	18	11	5	6	2	4	—	—	—	—	—	—	—	177	
	.50	—	—	31	1	11	9	5	8	13	—	1	—	—	—	2	—	—	—	—	81	
	.75	—	—	1	—	1	1	1	—	1	—	—	—	—	—	—	—	—	—	—	5	
	1.0	—	—	4	—	1	1	3	2	—	—	1	—	1	—	—	1	—	—	—	14	291
Thatcher 13-16, Nitrated, Pruned, Cultivated	.12	16	22	6	6	3	1	3	—	—	—	—	—	—	—	—	—	—	—	—	57	
	.25	24	15	40	12	16	12	12	6	1	6	1	—	—	—	—	—	—	—	—	145	
	.50	1	3	3	2	5	1	2	5	1	—	—	1	—	—	—	1	—	—	—	25	
	.75	—	—	2	—	5	2	6	—	—	2	—	—	—	—	—	—	—	—	—	17	
	1.0	1	—	—	—	—	7	7	5	1	1	3	—	2	—	—	—	—	—	—	27	271
Thatcher 14-13, Mulched '24, Nitrated, Cultivated	.12	4	41	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	46	
	.25	78	47	2	12	2	6	1	3	2	1	—	—	—	—	—	—	—	—	—	154	
	.50	—	21	30	1	7	—	5	4	—	1	2	—	—	—	—	—	—	—	—	71	
	.75	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	
	1.0	—	4	4	—	5	2	1	1	—	3	—	—	1	—	—	—	—	—	—	21	292
Thatcher 14-15, Pruned, Cultivated, Nitrated	.12	3	8	6	3	2	1	1	2	—	2	—	—	—	—	—	—	—	—	—	28	
	.25	11	11	42	18	27	10	16	7	5	2	4	—	2	1	2	—	—	—	—	158	
	.50	2	4	2	7	3	10	15	1	4	2	1	1	2	1	1	1	—	—	—	58	
	.75	1	—	2	1	3	—	3	1	1	1	1	—	1	—	2	—	—	—	—	17	
	1.0	—	—	—	—	—	4	—	2	3	1	1	—	1	1	—	—	—	—	—	13	274
Arcadia 10-6, Check	.12	133	13	3	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	152	
	.25	68	21	3	—	1	—	3	—	—	—	—	—	—	—	—	—	—	—	—	96	
	.50	3	4	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11	
	.75	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	
	1.0	8	3	3	—	3	—	—	1	—	—	—	—	—	—	—	—	—	—	—	18	279

TABLE V—SPUR GROWTH AS INFLUENCED BY TREATMENT. YORK IMPERIAL

Tree	Spur class	Growth year 1921	1922	1923	1924
Thatcher 7-8 Pruned, Side, Nitrated, Cultivated	.12	83	24	46	37
	.25	150	166	170	110
	.50	62	77	74	67
	.75	—	1	—	6
	Total	295	268	290	220
Thatcher 7-8, Unpruned, Side, Nitrated, Cultivated	.12	135	88	116	50
	.25	120	134	128	129
	.50	45	66	50	81
	.75	—	2	—	—
	Total	300	290	294	260
Thatcher 13-13, Nitrated, Pruned, Mulched 1923, Cultivated	.12	181	50	148	48
	.25	82	95	98	93
	.50	10	16	16	27
	.75	4	5	1	11
	Total	277	266	263	179
Thatcher 13-15, Nitrated, Cultivated, Not pruned, Mulched	.12	206	165	161	109
	.25	64	93	91	100
	.50	11	15	23	37
	.75	3	3	4	2
	Total	284	276	279	248
Thatcher 13-16, Pruned, Nitrated, Cultivated	.12	190	161	166	58
	.25	92	112	109	107
	.50	10	12	11	59
	.75	—	—	1	10
	Total	292	285	287	234
Thatcher 13-18, Nitrated Cultivated	.12	187	128	109	196
	.25	97	121	164	73
	.50	5	24	8	17
	75	—	—	—	2
	Total	289	273	281	288
Thatcher 14-16, Nitrated, Cultivated	.12	215	181	169	125
	.25	73	93	113	128
	.50	9	12	6	20
	.75	—	1	—	3
	Total	297	287	288	276
Thatcher 14-18, Pruned, Nitrated, Cultivated	.12	174	152	132	57
	25	115	125	139	90
	.50	2	7	8	35
	.75	—	1	—	5
	Total	291	285	279	187

Tree	Spur class	Growth year 1922	1923	1924
Arcadia 8-4, Nitrated, Disked	.12	24	76	208
	.25	191	206	78
	.50	56	15	8
	.75	—	—	1
	Total	271	297	295
Arcadia 9-3, Pruned, Nitrated, Disked	.12	154	126	207
	.25	61	141	73
	.50	33	15	6
	.75	4	2	3
	Total	252	284	289
Arcadia 9-4, Pruned, Nitrated, Disked	.12	19	70	75
	.25	138	187	160
	.50	80	29	28
	.75	0	0	0
	Total	237	286	263
Arcadia 9-5, Pruned, Nitrated, Disked	.12	157	178	160
	.25	70	86	82
	.50	27	15	9
	.75	3	3	—
	Total	257	282	251
Arcadia 9-6, Pruned, Nitrated, Disked	.12	23	54	67
	.25	191	207	91
	.50	47	23	31
	.75	—	—	0
	Total	261	284	189
Arcadia 10-6, Check	.12	147	155	219
	.25	39	95	45
	.50	17	11	16
	.75	2	2	1
	Total	205	263	281
Sleepy Creek 15-2, Pruned, Nitrated, Cultivated	.12	107	102	31
	.25	76	72	58
	.50	17	20	23
	.75	8	8	4
	Total	208	202	116
Sleepy Creek 15-3, Special Pruning, Cultivated	.12	174	165	69
	.25	85	96	89
	.50	36	31	56
	.75	—	—	6
	Total	295	292	220

ing has not produced much of a growth in the spurs of the older trees in either the Thatcher or Arcadia orchard, (See trees 7–8, 13–8 and 8–4). Pruning with and without nitrate of soda can be compared in trees 15–2 and 15–3 at Sleepy Creek. There was a tendency in the Thatcher trees to get better growth in both spurs and terminals the second year after the initiation of the treatments than the first. These data emphasize the value of combining pruning and nitrating in increasing growth in older York Imperial trees if any appreciable spur stimulation is to be obtained.

The growth response of some of the Sleepy Creek trees is shown in more detail in table VI. The elongation of 1923 of each growth was entered in a correlation table with reference to that made in 1924. The frequency distribution only of the growths falling into the different classes is given in the table for each year. It will be noted that the total number of growths measured on each tree is relatively large.

The frequency distribution of the growths during 1923 indicates the general state of vigor of these trees. No check trees are entered to show the relative growth between the 2 seasons on untreated trees. It was the intention to leave tree 17–3 as a check, but nitrate was applied by mistake. Each of the different treatments produced a good response on trees bearing a light crop and in Table I it will be seen that the amount of bloom was materially increased. On account of the spring frosts at bloom, however, the yield cannot be considered as representative of a normal season although it is very variable between the different trees

The special pruning given trees 15–3 and 15–4 gave a different response with nitrate of soda as a variable. Likewise, heading back the terminal limbs to a pencil size in the other 4 trees shows the difference in spur growth with 4 or 10 pounds of nitrate of soda. The better distributed pruning in tree 15–3 without nitrogen gave a greater spur stimulation and practically as much terminal growth as 10 pounds of nitrate with only the heading back.

It will be seen from these data, therefore, that different treatments influence spur and terminal growth in different degrees, but generally in the same direction if growth is increased.

The influence of growth upon yield: The last 4 seasons in eastern West Virginia have been unusual in the unfavorable weather prevalent at bloom. Frosts, freezes and excessive rain, and even snow, have lowered the yields in York Imperial in most orchards. In addition to this the midsummer season of 1923 and 1924 were unusually dry. It is difficult to evaluate the influence of these features of the seasons during which these studies were under way, but in spite of them there are some interesting tendencies in the influence of the different variables in the treatment upon the fruit produced.

The crop in the Thatcher orchard for 1924 on the pruned and unpruned trees is entered in Table VII separately in order to determine more readily the size differences in the 2 groups. No attempt was made in this orchard to get the same number of trees under each treatment so that the total yields cannot be considered as compar-

TABLE VI—SPUR GROWTH AS INFLUENCED BY TREATMENT. COMPARISON IS MADE BY COMPARING THE 1923 GROWTH BEFORE THE TREATMENT WITH THAT OF 1924 WHICH FOLLOWED IT

Tree	Treatment			Gr'th made	Classes for different lengths																				Total
	Pruned	Nitrated	C'lt d	in	.12	.25	.50	.75	1.0	1.5	2	3	4	5	6	8	10	12	14	16	18	20	22	24	
Sleepy Creek 15–3	One-half spurs and branches pruned out	none	Culti-vated	1923	252	123	14	6	6	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	404
				1924	33	131	90	23	18	11	21	10	11	11	18	8	14	3	1	1	—	—	—	—	404
Sleepy Creek 15–4	One-half spurs and branches pruned out	6 pounds	Culti-vated	1923	252	97	33	3	16	7	8	1	2	—	—	—	—	—	—	—	—	—	—	—	419
				1924	25	135	76	16	16	9	17	12	17	15	18	24	13	6	6	7	3	3	1	1	420
Sleepy Creek 16–3	Headed back to a pencil size	4 pounds	Culti-vated	1923	382	34	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	420
				1924	207	141	28	8	4	2	10	11	2	6	—	1	—	—	—	—	—	—	—	—	420
Sleepy Creek 16–4	Headed back to a pencil size	4 pounds	Culti-vated	1923	325	72	16	4	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	420
				1924	193	113	50	5	22	8	7	8	3	3	5	2	1	—	—	—	—	—	—	—	420
Sleepy Creek 17–3	Headed back to a pencil size	10 pounds	Culti-vated	1923	313	61	17	2	17	3	5	1	1	—	—	—	—	—	—	—	—	—	—	—	420
				1924	165	129	17	2	7	3	7	4	6	4	17	16	16	9	7	6	1	4	—	—	420
Sleepy Creek 17–4	Headed back to a pencil size	10 pounds	Culti-vated	1923	345	51	17	3	3	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	420
				1924	215	78	23	3	9	5	9	7	7	12	20	14	11	4	1	2	—	—	—	—	420

TABLE VII—YIELD RECORDS IN SELECTED TREES IN THE THATCHER, SLEEPY CREEK AND ARCADIA ORCHARDS. YORK IMPERIAL

	Tree	Treatment				Grades and yield 1924 crop, pounds						1925 crop, pounds		
						Pruned			Unpruned			Pruned		
		Pruned	Nitrate	Mulch	Cultivated	0–2¼	2¼–2¾	2¾–up	0–2¼	2¼–2¾	2¾–up	0–2¼	2¼–2¾	2¾–up
THATCHER	7– 8	none	9 pounds	none	cultivated	14	78	161	*43	220	103	—	—	—
	7– 9	detailed	9 "	"	"	17	190	346	—	—	—	—	—	—
	7–10	none	9 "	"	"	5	90	250	*5	300	135	—	—	—
	7–11	detailed	9 "	"	"	10	148	227	*49	262	173	—	—	—
	13–13	"	9 "	1923 straw	"	35	196	273	—	—	—	1	44	43
	13–14	½ "	9 "	"	"	27	220	155	*32	267	156	0	0	0
	13–15	none	9 "	"	"	—	—	—	*85	390	575	*1	12	13
	13–16	detailed	9 "	none	"	35	145	344	—	—	—	15	250	105
	13–17	½ "	9 "	"	"	0	0	0	*38	75	60	*0	15	30
	13–18	none	9 "	"	"	—	—	—	*72	391	325	*0	0	0
	14–13	none	9 "	1924 fodder	"	—	—	—	*30	157	308	*7	71	72
	14–14	½ detailed	9 "	none	"	0	0	0	*75	345	521	5	80	145
	14–15	"	9 "	"	"	5	110	129	—	—	—	28	138	260
	14–16	none	9 "	"	"	—	—	—	*42	205	298	*0	10	50
	14–17	½ detailed	9 "	"	"	—	—	—	*15	110	222	0	0	0
	14–18	detaied	9 "	"	"	105	425	605	—	—	—	40	125	75
						Grades and yield 1925 crop, pounds								
ARCADIA	8–3	none	8 pounds	none	disked	—	—	—	565	485	110			
	8–4	"	8 "	"	"	—	—	—	375	45	0			
	8–5	"	8 "	"	"	—	—	—	460	178	80			
	8–6	"	8 "	"	"	—	—	—	605	590	325			
	9–3	detailed	8 "	"	"	25	145	500	—	—	—			
	9–4	"	8 "	"	"	5	30	325	—	—	—			
	9–5	"	8 "	"	"	76	200	445	—	—	—			
	9–6	"	8 "	"	"	45	268	650	—	—	—			
	10–3	none	none	"	"	—	—	—	—	345	5			
	10–6	"	"	"	"	—	—	—	675	90	0			
						Grades and yield 1925 crop, pounds								
Sleepy Creek	15–1	detailed	6 pounds	none	cultivated	3	10	4						
	15–2	"	6 "	"	"	0	35	325						
	15–3	" spec.	none	"	"	0	2	25						
	15–4	" "	6 pounds	"	"	0	20	90						
	16–3	heading bk.	4 "	"	"	28	76	50						
	16–4	" "	4 "	"	"	0	46	45						
	17–3	" "	10 "	"	"	7	16	5						
	17–4	" "	10 "	"	"	65	5	0						

*Unpruned.

able. Then too, in the 2 trees 13–17 and 14–14 the pruned side happened to be off in 1914. Other trees also had a "spotted" bloom. One-half only of some of the trees were pruned in order to increase the number of trees included in the differential treatments.

In the trees of row 7 entered in Table VII it will be seen that nitrating, cultivating and pruning, have materially increased the amount of fruit in the size 2¾ up, as compared to the unpruned trees. The same tendency is shown in the trees in rows 13 and 14; especially in tree 14–18 which bore the heaviest crop of any of the pruned trees. The 1924 crop borne by 13–13 and the pruned half of 13-14 was interesting. The combination of detailed pruning, the mulch, 9 pounds of nitrate of soda and cultivation, produced such a vigorous spur growth, especially in diameter in the short classes that 96 per cent of the spurs blooming set fruit. Not only that, out of 450 spurs upon which the number of fruit set was determined, 179 had set 1 fruit; 154 set 2; 87 set 3; 25 set 4; and 5 spurs set 5 fruits. Thinning was purposely omitted so the increased set actually reduced the size as compared with other treatments. The spurs setting on tree 15 which received the same treatment except that it was not pruned were 79 per cent. Out of 225 spurs upon which the number of fruit which set was determined on this tree, 149 set 1 fruit; 66 set 2; and 10 set 3 fruits. The sizes produced on tree 13–15, which was mulched, but not pruned or thinned, are interesting, especially when compared with the other pruned trees which received nitrate and cultivation, but no mulch. The 1925 crop was light and the yields are given for comparison. Some of the trees show a tendency to repeat, but emphasis is not placed upon this because of the weather conditions at bloom and also the possibility of limb alternation.

Turning now to the Arcadia orchard it will be seen that the influence of the pruning and nitrating are comparable to the results in the Thatcher orchard although more pronounced. It will be appreciated by those who have given this problem study that the real test of the progress in correcting biennial bearing comes after the first crop year in trees of this age which have been "renovated." The pruning and nitrating in the 4 trees in row 9 have materially increased the size of fruit as compared to the 4 trees in row 8 which were nitrated but not pruned. The 2 check trees in row 10 produced still greater quantities relatively of the smaller sizes, than the trees in row 8. From Table II it will be seen that the spur growth was short in tree 10–6. The pruning has probably reduced the yield in row 9, 2724 pounds, as compared with the total yield in row 8 of 3818 pounds, although more trees should be included if conclusions in this direction are to be given weight.

Of the yield in the Sleepy Creek trees not much can be said. The bloom was increased and the growth stimulated so that it is probably safe to say that a start toward increased production has been made. Experiments, however, extending over 11 years in the Sleepy Creek experiment in adjacent trees, indicate that progress in raising the yield level in this particular orchard is relatively slow.

It will be seen from the foregoing that the different treatments have a marked effect upon fruit production as well as upon bloom and growth. The data show, however, that it is necessary to give attention to the combinations in the treatment in order to produce a given effect.

Summary

1. The habit or form of tree brought about by the first period of heavy production appears to have a far reaching influence upon growth and through this upon bloom, set and size of fruit. The alternation of limbs in both bloom and yield suggest an individuality of these larger units of the tree which is apparently not so directly influenced by the condition of the tree as a whole. From a casual examination of the relation of these larger limbs to the trunk and root system it appears that they are in a large measure separate entities although integral parts of the tree and that the older the tree the more pronounced appears to be this tendency.

2. When making a slow growth or in old unpruned trees this variety tends to develop far too many growing points. The terminals under these conditions gradually reach the status of spurs in both growth and performance. A well distributed type of pruning, or a combination of nitrate and pruning, seems to be required to bring about a pronounced spur or terminal growth. In responding to these cultural treatments there is a tendency for increased growth to be general among the spurs, but the longer ones make the greater growth.

3. The bloom indicates the condition of the tree as well as growth. In the on year all growths tend to bloom, including the terminals, if checked in growth the previous summer by drouth. The better the condition of the unpruned tree the greater is the tendency for the shorter growths to bloom and set. In the thick unpruned tree as in the Arcadia orchard, heavy nitrate applications tend to stimulate growth, bloom and set in the shorter growths, and thus to increase the yield in the smaller sizes. Complete alternation and the nearest non-blooming condition were found in these studies to be associated with the shortest spur growth.

4. In interpreting the effect of the different variables entering in the treatment of these trees the following series can be constructed with reference to the effectiveness of the different combinations: (1) the check trees under study indicate that but little can be expected from York Imperial in the direction of raising the standard of fruit produced without giving attention to the cultural details. (2) With slow growing trees on poor soil, or old trees which have been bearing heavily, but which are in need of pruning, the application of nitrate of soda alone in the usual quantities is not sufficient to materially influence the growth or to increase the size of fruit. (3) Under the tree conditions of number 2, a well distributed pruning alone, or pruning with nitrate of soda, will bring about a correction in both growth and size of fruit which can not be approached by nitrating alone. When used for this purpose the detailed pruning alone

gave a growth response on unproductive 20 year old trees which was about the equivalent of 3 pounds of nitrate of soda. (4) When cultivation and mulching are combined with pruning and nitrating it is possible to go too far in stimulating spur growth and set so that the size of fruit may be reduced in the absence of thinning because of the increased set.

5. From the results reported here, if yield is to be taken as the criterion, it does not appear that much progress has been made in correcting the biennial bearing habit in York Imperial. From the standpoint, however, of building up a background which would tend in this direction some progress has been made.

The Relation of Leaf Area to the Growth and Composition of Apples

By M. H. Haller and J. R. Magness, *U. S. Dep't Agr., Washington, D. C.*

Introduction

FROM the practise of thinning it is known in a general way that, by diminishing the number of fruit and thus increasing the leaf area of each remaining fruit, the size of this fruit is increased. Up to the present time, however, practically no experimental data have been presented which show the exact relation between the leaf area or number of leaves to each fruit and the size and composition of the fruit. Neither is it known to what extent the fruit is dependent upon leaves which are immediately adjacent to it, or whether it may draw upon foods which are elaborated at considerable distances. Information on these points is fundamental to studies of growth and chemical composition of fruits, maturity of the fruit, and the relation of fruit production to tree growth and fruit bud formation. Information on these points is also basic to thinning practise.

Outline of Procedure

In order to throw some light on these problems, experiments were conducted in the apple variety orchard of the United States Department of Agriculture at Arlington, Virginia, during 1924 and 1925. The varieties used during 1924 were Winesap, Ben Davis, Delicious and Rome Beauty. Spurs or twigs were ringed and thinned to one apple and varying numbers of medium sized leaves as follows: 0, 1, 2, 4, 6, 10, 15 and 20. The ringing was done from May 5, at which time the petals were falling, to June 24 when the fruit was one-half to three-fourths inch in diameter, the varieties being ringed in the order named. In ringing, a strip of bark was removed one-sixteenth to one-eighth inch wide and the wound covered with wax. Many of

the rings healed over and it was necessary to rering such twigs the middle of August.

Each apple was numbered so that records of individual apples were kept throughout the summer. Circumference measurements of the apples and notes as to dropping were taken at intervals of 10 days. The circumference of the apples was taken at their greatest transverse diameter. Similar records were kept of apples on branches which were not ringed.

Ringing small twigs bearing individual apples resulted in considerable injury. The results secured in 1924 were quite variable, but indicated clearly a relationship between the leaf area and the size of the fruit. The results also indicated clearly that even 20 leaves, the maximum used in 1924, was not a sufficient number to give good size and quality in apples.

During 1925 the varieties used were Delicious, Ben Davis and Grimes. The maximum number of leaves per fruit was increased from 20 to 75 and 80 and certain of the smaller numbers were eliminated. The rings were made larger, one-fourth to three-eights inch wide, in order to prevent healing over of the rings. Injury from ringing was lessened by using larger limbs and then leaving several fruits evenly distributed above the ring, but with a constant number of leaves per fruit. In case an apple on such a limb dropped off, a sufficient number of leaves was removed so that the average per apple was unchanged. In case any new leaves appeared following the ringing these were removed. The apples were harvested in the fall and samples taken from each treatment to determine the per cent of dry weight, sugars and acids.

During 1925 an experiment was conducted with Grimes apples to determine the effect of the distance of the leaves from the fruit on its growth. Branches were ringed leaving above the ring 1 fruit and 20 leaves, the leaves, however, being varying distances from the fruit. In some cases the leaves were all immediately adjacent to the fruit and varied to cases in which no leaves were within 90 centimeters of the fruit. Growth measurements of the fruit were made throughout the summer. A sample of 100 average leaves of each variety was measured with a planimeter to determine the average area per leaf.

Presentation of Data

The results for 1925 are presented in Table I which shows the number of fruits which remained at the time of the last measurements, the average increase in volume per apple, the average weight per apple at the time of harvest, the dry weight in per cent of the fresh weight, the per cent of acid as malic acid and the per cent of total sugars on the fresh weight basis.

The volume of the fruit was determined from the circumference measurements by the formula for determining the volume of a sphere ($^1/_6 \Pi D^3$). This assumes the fruit to be a perfect sphere which is incorrect. The figures obtained, however, are comparable and more truly represent the amount of growth which the fruit has made

TABLE I—RELATION OF LEAF AREA TO NUMBER OF APPLES SETTING, INCREASE IN SIZE, AND CHEMICAL COMPOSITION OF APPLES IN 1925

Variety	Leaves		Number of apples		Average increase in volume per apple, cubic centimeters	Average fresh weight per apple at harvest, grams	Dry weight of fruit per cent of fresh weight	Acid as malic per cent of fresh weight	Total sugar as glucose per cent of fresh weight
	Number per fruit	Area per fruit, square inches	When ringed	Late in season					
				September 21	June 6 to September 21, 107 days	September 26			
Ben Davis	0	0	25	0	—	—	—	—	—
	5	14.4	25	13	43.4±3.1	41.6	12.6	.315	9.40
Ringed	10	28.7	25	19	64.2±2.7	55.7	12.7	.342	9.85
	20	57.4	25	18	98.4±2.6	79.4	14.1	.308	11.00
June 3–5,	30	86.1	25	22	123.6±2.4	96.8	16.9	.360	12.40
	50	144.0	25	23	148.6±3.6	112.9	18.1	.443	13.30
	25	225.3	25	17	152.8±4.5	113.8	19.4	.462	15.15
1925	*42	120.5	45	39	129.8 —	—	15.4	310	11.75
				August 25	June 1 to August 25, 85 days	September 19			
Delicious	0	0	40	9	5.6±0 5	—	—	—	—
	5	12.5	40	37	28.3±1.4	38.1	11.2	241	8.10
Ringed	10	24.9	40	33	54.7±1.7	62.3	11.9	.182	10.05
	20	49.8	40	37	85.8±2.4	92.2	13.3	.198	11.60
May 8 to	30	74.7	40	30	108.8±2.5	117.5	15.7	.198	12.35
June 3,	50	124.5	40	19	118.9±4.0	132.1	18.1	.230	14.45
	75	186.8	35	19	153.6±9.4	153.0	19.4	.245	15.95
1925	*50	124.5	32	30	137.3 —	148.1	15.2	.228	12.45
				August 26	June 19 to August 26, 68 days	September 15			
Grimes	0	0	35	28	7.2±0.3	26.9	12.7	.310	7.80
	5	10.2	30	29	25.3±0.7	43.1	15.3	.315	11.65
Ringed	10	20.4	30	26	43.1±1.6	57.3	16.1	.293	12.10
June 17–18,	20	40.8	30	25	87.7±1.8	96.6	17.3	.335	13.90
1925	40	81.6	30	18	124.2±2.8	124.7	18.8	.350	14.35
	80	163.2	30	16	128.4±4.3	123.1			
	*44	89.8	34	33	95.3 —	105.2	16.8	.295	13.70

*On unringed branch.

than do the circumference measurements. The average increase in volume was obtained by subtracting the average volume of the fruit at the time the first measurements were taken from that at the time of the last measurements, only those apples which remained at the last measurement being considered in the averages of the first measurements.

TABLE II—COEFFICIENTS OF CORRELATION BETWEEN THE INCREASE IN VOLUME OF THE APPLES AND THE NUMBER OF LEAVES PER APPLE

Variety	Year	Leaves	Correlation
Rome Beauty	1924	1 to 20	r = .9755 ± .0020
Ben Davis	1924	4 to 20	r = .5938 ± .0384
Ben Davis	1925	5 to 75	r = .7428 ± .0285
Ben Davis	1925	5 to 30	r = .9334 ± .0102
Ben Davis	1925	30 to 75	r = .4201 ± .0705
Delicious	1924	4 to 20	r = .4226 ± .0440
Delicious	1925	0 to 75	r = .8048 ± .0175
Delicious	1925	0 to 30	r = .8711 ± .0163
Delicious	1925	30 to 75	r = .5619 ± .0560
Grimes	1925	0 to 80	r = .8295 ± .0096
Grimes	1925	0 to 40	r = .9402 ± .0070

In Table II is shown the correlation between the increase in growth of the apples and the number of leaves per apple.

EFFECTS OF RINGING

The effect of ringing according to the work of Curtis (1) (2) Gardener (3) and others is to prevent the translocation of carbohydrates and also nitrogen in either direction past the ring. Thus the apples on ringed branches would be prevented from drawing upon carbohydrates from below the ring, but would have available to them all of the carbohydrates elaborated by the leaves above the ring. The fruit and leaves on the branches above the rings might be considered as physiologically isolated drawing from the tree only water and possibly some salt materials.

EFFECT OF LEAF AREA ON THE SIZE OF THE FRUIT

There was a strong correlation between the leaf area and the increase in volume of the fruit, Table II, up to a certain point beyond which a further increase in the number of leaves did not result in a correspsnding increase in volume. In 1925 the growth of Grimes apples was as great with 40 leaves as with 80, while the Ben Davis apples with 75 leaves increased only slightly over those with 50 leaves. The Delicious apples, however, continued to increase in volume with an increase in leaf area up to 75 leaves per apple. Table II shows that the increases in growth for the apples with the high leaf areas were not correspondingly great as compared with those of smaller leaf areas, since lower coefficients of correlation were secured between the groups with the high leaf areas than were secured in the groups with the small leaf areas. In the Ben Davis the correlation coefficient for the apples with 5 to 30 leaves is .9334 ± .0102

as compared with .4201 ± .0705 for those with 30 to 75 leaves. In the Delicious the correlation coefficients are .8711 ± .0163 for the apples with 0 to 30 leaves and .5619 ± .0560 for those with 30 to 75 leaves.

Apples grown with no leaves made a slight increase in volume. Since the skin of the apple contains chlorophyll it may be that the small amount of food necessary for this growth was elaborated in the skin. It is also possible that there was sufficient stored food in the branches above the rings to have accounted for the small amount of growth made.

The average weight of the apples at harvest corresponds to the increase in volume as shown in Table I. It is interesting to note that the differences in dry weight are even more marked than are the differences in fresh weight. This is shown by the percentage dry weight determinations which are very much greater in the apples that were grown with a large leaf area. In Grimes the dry weight varies from 12.7 per cent for apples grown with no leaves to 18.8 per cent for those grown with 80 leaves. In the Delicious the dry weight varies from 11.2 per cent to 19.4 per cent for apples grown with 5 and 75 leaves respectively. In the Ben Davis it varies from 12.6 to 19.4 per cent for apples with 5 and 75 leaves respectively.

The growth of apples on unringed branches usually fell somewhat below that of apples on ringed branches, having the same number of leaves. This was probably due to the translocation of carbohydrates away from the apples before they were able to use them in the unringed branches while they were kept close enough to be available on the ringed branches.

Effect of Leaf Area on the Ripening and Quality of Apples

The ripening of the fruit is hastened by a large number of leaves. Apples with no leaves remained leaf green until picked, and were to all appearances in the same condition of maturity as when ringed. The ground color of apples with 5 to 10 leaves and even 20 leaves remained quite green while those with 30 to 75 leaves turned yellowish and showed a somewhat higher per cent of blushed surface. The apples with the high numbers of leaves also started to drop sooner in the fall than did those with small leaf areas, all of which indicates that the apples with the high leaf areas were more mature when harvested than were those with low leaf areas.

There were very decided differences in the flavor and quality of the apples depending on the number of leaves with which they were grown. In general the apples grown with 40 or more leaves were sweet and well flavored for the variety. With 30 leaves there was a slight dropping off in quality, the apples being slightly sour and of only fair flavor. With 20 or less leaves the apples were of a disagreeable flavor and quite sour.

The quality of the apples depends to a large extent on the amount of sugars and acid which they contain. The sugar determinations for Rome Beauty apples in 1924 showed a dropping off in the total sugars

from 9.72 per cent for fruit grown with 20 leaves to 7.54 per cent for fruit grown with 1 leaf. The Grimes in 1925, Table I, showed a dropping off in total sugars of 14.35 per cent for apples grown with 40 and 80 leaves to 7.80 per cent for those grown with no leaves. The Delicious showed an even greater dropping off of 15.95 per cent for apples grown with 75 leaves to 8.10 per cent for those grown with 5 leaves which is nearly 100 per cent increase in sugar content from apples grown with 5 leaves to those grown with 75 leaves.

The acid determinations for 1925 (Table I) show a similar dropping off in the per cent of acid in apples which were fairly mature at harvest with a lowering of the leaf area. With those apples, however, which were extremely immature and grown with 20 leaves or less, there is usually an increase in the per cent of acid with a further lowering of the leaf area.

Effect of Leaf Area on the Dropping of Leaves

During 1925 it was noticed that some of the leaves on the ringed branches turned yellow and dropped off during the summer. A count of the leaves remaining was made on August 8 and 10. This disclosed that the dropping was from the branches having a high number of leaves per fruit. In the case of the Grimes 42 per cent of the leaves had dropped from the branches which started with 80 leaves per fruit, 29 per cent from those with 40 leaves per fruit, 6 per cent from those with 20 leaves per fruit and none from those with 10 and 5 leaves per fruit. In the case of Delicious the per cent dropped was 11, 12, 10, 4, 3 and 0 from branches having 75, 50, 30, 20, 10 and 5 leaves per fruit respectively. For the Ben Davis the per cent drop was 23, 9, 1, 1, 0 and 1 from branches with 75, 50, 30, 20, 10 and 5 leaves per fruit respectively. The cause of this dropping is not known. In the branches with the large number of leaves per fruit, carbohydrates are probably elaborated more rapidly than the fruit is able to use them, resulting in an accumulation of the excess in the twigs and leaves which may have caused the leaves to drop. That there is an accumulation of carbohydrates in the branches with the large leaf area per fruit is also indicated by the fact that there was a much heavier callus formation at the ring on such branches as compared to branches with a small leaf area per fruit.

Effect of Leaf Area on Fruit Dropping

The number of fruits dropping decreased with an increase in the leaf area per fruit until a certain leaf area was attained. As was to be expected the leaf area necessary to attain minimum dropping was less than that necessary to attain good size and quality. In most cases minimum dropping was attained with 10 to 20 leaves per fruit. This depends however on the time at which the treatments were applied. When the ringing was done the latter part of June, with the fruit about three-fourths of an inch in diameter, there was little effect of the leaf area on the dropping, as fruit with no leaves adhered until fall under those conditions.

The Effect of Leaf Distance on the Growth of Apples

In the case of the apples grown with a large leaf area some of the leaves were at considerable distances from the fruit, frequently over 50 centimeters. In order to determine whether the fruit could draw upon leaves which were at such a distance an experiment was conducted in which the fruit was grown on ringed branches with 20 leaves, which were at varying distances from the fruit. The data for this experiment are not presented as the test was conducted with only 1 variety and during only 1 year. The data, however, strongly indicate that apples are able to draw upon leaves which are as much as 100 centimeters away and upon leaves which are adjacent to the fruit with almost equal facility.

Discussion

The data indicate that under the conditions prevailing during 1925 in the Arlington orchard, the size of the fruit was directly related to the leaf area, if less than 40 leaves per apple were present in Grimes, if less than 50 leaves were available in Ben Davis, and there was a strong correlation when even 75 leaves were available in Delicious. When a much smaller number of leaves was present, the fruit was small in size, low in dry weight, low in sugar content and of poor dessert quality.

These data are of much interest in connection with problems not only of thinning and fruit growth and quality, but also of fruit bud formation and alternate bearing. They indicate that when an apple is produced, it must draw on synthesized foods from leaves away from its immediate spur. On heavily loaded branches and trees, there is often not more than 20 or 30 leaves per apple, and under these conditions the fruit is small and of poor quality. It is probable that under these conditions, most of the carbohydrate material formed in the leaves is used in the fruit. Murneek (4) has pointed out the fact that in the tomato, fruiting tends to inhibit vegetative growth. In the apple, it would appear that heavy fruit production might utilize practically all available synthesized material in the tree.

Since such a large leaf area appears necessary to the proper development of an apple the importance, in a study of spur behavior, not only of whether or not an individual spur is bearing fruit, but the proximity of other spurs bearing fruits, is apparent. This is particularly true in view of the fact that the fruit can apparently draw upon leaves at considerable distances for its synthesized food materials.

The data on chemical composition of apples grown with varying leaf areas emphasize the relation between the amount of crop on the tree and the dessert quality of the fruit. The effect of thinning on size of fruit has been generally recognized, but the effect on quality has received far less emphasis. The Delicious, which in these tests required the largest leaf area for proper development, is of notoriously poor quality, if the trees are allowed to bear too heavily.

Summary

Other factors being constant the growth in volume and weight of apples is directly correlated with the leaf area upon which the apples are able to draw for carbohydrates up to the point at which maximum growth is obtained. For the Grimes and Ben Davis under the conditions of this experiment at least 30 to 40 medium sized leaves per fruit were necessary to obtain apples of good size and quality, while Delicious required even more.

A higher per cent of dry weight, sugars and acids is associated with apples grown with a large leaf area as compared with apples of the same variety grown with a small leaf area.

Apples grown with a large leaf area ripen earlier and are of higher quality than those of the same variety grown with a small leaf area.

Apples are not dependent upon leaves which are immediately adjacent, but apparently are able to draw upon leaves which are as much as 100 centimeters away.

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Is Fruiting of the Apple an Exhaustive Process?

By A. E. Murneek, *University of Missouri, Columbia, Mo.*

BASED upon an extensive investigation of the effects of correlation between fruit and vegetative growth in the tomato, the writer presented evidence in 1924 that the fruits of this plant have a most extraordinary power for absorbing practically all of the important plant constituents (9, 10). The most commonly recognizable features of this effect were found to be a disarrangement of the normal functions of the succeeding reproductive organs and a marked reduction, and in extreme cases a complete cessation of further vegetative development. Both the external symptoms and chemical analyses pointed to nitrogen as a limiting factor. The tomato fruit in some way is able to monopolize all of the available nitrogen supply.

The present paper deals in a preliminary way with (a) the relative distribution of nitrogen in the organs comprising the spur system of

the apple, and (b) the comparative amounts of nitrogen removed by the apple fruit. As our current information on the question of the character and degree of exhaustion of the apple tree by its fruit is at best still very incomplete, it may be only a subject for discussion.

That the reproductive functions, particularly when followed by the development of a comparatively massive organ, the fruit, may have a devitalizing effect on the plant, has probably been recognized and appreciated as early as fruit has been grown (13). There is total lack of information, however, as to the extent to which this may be true in some of our common fruit trees, for example the apple.

Limiting ourselves to nitrogen as one of the most important ingredients in the make-up of the fruit tree, a number of investigators (15, 3) have shown that of the some 50 pounds of nitrogen removed annually from an acre of ground by average bearing apple trees, approximately 40 per cent goes into the crop. It has been also estimated that this constitutes somewhere near two-thirds the amount that falls with the leaves (15, 4) and that the quantity of nitrogen utilized in permanent vegetative extension is rather insignificant. This comparison is open to further verification. Practically all of the analyses of fruits have been made on the pulp only. There is hardly any doubt that considerable quantities of nitrogen in the flesh of the fruit are eventually translocated to the seeds. On the other hand, it is very likely that in years of normal autumnal defoliation a much larger share of nitrogen is returned to the tree from the leaves than is usually estimated, for most of the data have been based on leaves still attached to the plant.

Assuming that about one-half of the total nitrogen supply of the apple tree finds its way into the fruits, the question naturally arises whether this puts any strain upon the resources of the plant. May there not be instances at certain times of the growing season when competition for the available supply is rather keen between the developing fruit and other organs? This certainly was found to be the case in the tomato.

To throw some light upon this subject a series of investigations was initiated by the writer in the spring of the current year. The problem naturally resolved itself into securing of evidence of competition for the synthesized substances (a) among organs forming the spur system, (b) parts comprising the branch or limb, and (c) in the tree as a whole. Both statistical and chemical methods are employed. Bearing trees growing in the University orchard at Columbia are being used as material. The experimental treatment consists at present largely of removal of flowers and fruits in various stages of development.

Results of chemical analysis for total nitrogen in organs of the spur system of 2 varieties of apples are presented herewith:

The usual seasonal decrease of percentage composition in all parts of the spur system is clearly evident (Table I). In general, the figures agree very well with those of other workers (6, 7, 14, 11). The most rapid decrease is to be noted in the fruits. Analysis of the fruit in every case, of course, included the seeds also.

TABLE I—PER CENT TOTAL NITROGEN IN ORGANS OF THE APPLE SPURS SYSTEM; JONATHAN AND PAYNES LATE KEEPER—DRY WEIGHT BASIS

	April 15	May 1	May 15		June 15	July 15			August 15
	Check	Check	Check	Deflorated (April 15)	Check	Check	Deflorated (April 15)	Defruited (May 15)	Check
Jonathan									
New growth	3.81	2.99	2.11	1.51	1.85	1.53	1.23	1.30	—
Old growth	.86	.97	.92	.79	.81	.91	.90	1.02	—
Flowers or fruits	3.20	3.32	1.82	—	.93	.65	—	—	.42
Leaves	3.11	2.83	2.31	2.31	1.83	1.72	1.83	1.80	—
Paynes Late Keeper									
New growth	3.80	3.19	2.19	1.71	2.18	1.43	1.52	1.69	—
Old growth	1.09	—	1.08	.98	.94	1.01	1.17	1.23	—
Flowers or fruits	3.18	2.75	1.88	—	.96	.76	—	—	.38
Leaves	3.09	2.92	2.57	2.46	2.09	1.09	2.05	2.15	—

TABLE II—GRAMS TOTAL NITROGEN IN ORGANS OF THE APPLE SPURS SYSTEM; JONATHAN AND PAYNES LATE KEEPER—BASIS OF 100 SPURS

	May 1	May 15		June 15	July 15		
	Check	Check	Deflorated (April 15)	Check	Check	Deflorated (April 15)	Defruited (May 15)
Jonathan							
New Growth	.144	.112	.116	.109	.127	.097	.116
Old Growth	.133	.142	.169	.094	.133	.207	.122
Fruits	.183	.828	—	2.670	6.701	—	—
Leaves	.711	1.121	1.290	.815	.814	1.231	.940
Paynes Late Keeper							
New growth	.128	.118	.099	.148	.114	.128	.123
Old Growth	—	.143	.123	.109	.093	.142	.117
Fruits	.071	.586	—	2.010	4.385	—	—
Leaves	.535	.859	.971	.907	.796	1.283	1.058

A somewhat different picture presents itself, however, when the results are expressed in grams of total nitrogen (Table II). Immediately after flowering or beginning with May 1, there is apparently no more change in the total amount of nitrogen in either the new or old parts of the spur. Likewise, absorption of nitrogen by the leaves for their complete development, most likely takes place very early in the season. Thus at the time of flowering by far the largest share of total nitrogen (61 per cent and 62 per cent respectively) is found in leaves, the greatest competitors with the flowers and fruits for the current supply. It is significant that when the spur is deflorated or defruited, the total quantity of nitrogen is increased in the older part of the spur, but particularly in leaves. The greatest benefit in this respect seems to be gained from an early removal of reproductive organs—defloration. Naturally one would expect that the new growth of the spur should also be benefited by the treatment. This most probably would be the case were it not for the fact that in all essentials of development it is already completed by this time.

Particular emphasis should be placed upon the total quantity of nitrogen going into the fruit. On July 15, approximately 10 weeks after fertilization, 86 per cent and 82 per cent of the total nitrogen of the spur system was concentrated in the fruits of the 2 respective varieties. At this time, naturally, the apples were but half grown. Hence, still further augmentation in nitrogen content coincident with their normal increase in size must be expected. The relative amount of nitrogen in the leaves at this period is incomparably smaller. In fact, having reached their maximal development early in the season, the leaves of the spur system may be considered the primary source of supply for the rapidly developing fruit, assuming, of course, that nitrogen is made available primarily through foliar synthesis.

The above results seem to indicate that in the early development of organs of the apple spur system the nitrogen reserves of the tree are utilized in greatest quantities by the leaves, and in lesser amounts by the flowers and fruits. Can this be considered one of the reasons why flowering of a large number of deciduous trees precedes the development of foliage? It has been demonstrated (6) that the removal of flowers increases the leaf area of the spur. On the other hand a reduction of the normal amount of foliage of the spur usually decreases the number of fruits set (6). Clearly, in this respect, the balance between the 2 organs is either very delicate or else it is not at all a matter of simple quantitative relationship. The question must be left open pending further accumulation of facts. One should, however, keep in mind the extraordinary results as regards increase in fruit setting and vegetative growth that have been obtained by the application of nitrogen in readily available form early in the spring. This, however, need not be discussed here.

Of equal significance in this consideration is the question of the really tremendous quantities of nitrogen that go into the fruit during the course of its development, which in late varieties of apples extends almost till the end of the functional period of foliage. We do

not know what proportion of it is elaborated by the leaves of a bearing spur. It is very likely that most of it is obtained from either the general reserves of the tree or the current sources of supply of the strictly vegetative parts further back of the spur system. The writer has demonstrated that when bearing spurs are completely defoliated, as many as 20 per cent of them are able to set and develop fruit of at least two-thirds of their normal size (6). Moreover, it has been indicated that the linear growth of non-bearing spurs is in inverse proportion to the crop of the tree as a whole and that bearing branches show a smaller diameter increase than non-bearing ones (8). Again, several investigations have shown that the fruits, particularly in years of heavy bearing, affect the tree as a whole by limiting vegetative growth, decreasing leaf area, and by reducing diameter of the trunk (2, 5, 1, 12). Hence, it seems to be very probable that fruiting of the apple is an exhaustive process, this being particularly true in years of a heavy crop and a limited nitrogen supply.

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Some Results of Bending the Branches of Young Apple and Pear Trees

By L. H. MACDANIELS and A. J. HEINICKE, *College of Agriculture, Ithaca, N. Y.*

STRIKING modification of the normal growth and fruiting habits frequently result from bending upright branches to more horizontal positions. This principle has long been in use for intensive training of fruit trees to unnatural forms (Langley, 1729). It was also known hundreds of years ago that vigorous young trees could be induced to bear fruit by suspending large stones from the ends of limbs. Recently Tufts (1925), has called attention to the experience of a grower in California -Mr. Caldwell- who has caused earlier fruiting of the young Bartlett pear trees by tying down the branches.

In New York State the Northern Spy apple and the Keiffer pear are among the varieties that have very upright growth habits especially while the trees are young and vigorous. While it would be possible to cause the trees to assume a more open and spreading form by pruning, such treatment would probably delay bearing and reduce the yields during the early crop years. This delay in bearing is especially noticeable in the Northern Spy apple which is characteristically later than most varieties in coming into fruiting. It seemed of interest to learn in a preliminary way whether these varieties would respond to bending in such a way that the necessary training could be done by tying down the branches rather than by heavy pruning and thus obtain earlier fruiting.

EXPERIMENTS WITH NORTHERN SPY TREES

The Northern Spy trees used for the experiment had made 9 seasons growth in the Cornell orchard at Ithaca, New York, when the experiment began in the spring of 1923. Practically no fruit had been borne previous to this time, but the trees blossomed and set some fruit during the season 1923. All of the 16 trees which had their branches tied down had been moderately pruned in previous years and also in the spring of 1923. Data obtained from these trees are compared with data from 12 trees in adjoining rows which had received about the same amount of pruning, and also with 12 other nearby trees that had been pruned very little.

The limbs were tied down in the spring before the growth started. On each tree, 3 to 5 large upright branches about 2 inches in diameter at the point of origin were pulled down to an angle of about 45 degrees. They were held in place by heavy wire which was fastened at one end to a screw eye inserted in the trunk at the surface of the ground, and at the other end to a somewhat lighter screw eye inserted in the branches where the diameter was approximately 1½ inches, and the distance from the point of origin, 3 to 4 feet. The ends of the branches were pulled lower than the middle portion so

that the arc caused by the bending was confined to the heavier wood near the trunk. It was necessary, of course, to exercise care to prevent splitting of the branches while they were being pulled into place. The injury caused by the insertion of the screws into the wood was hardly enough to interfere with the movement of food and water.

The average yields of the trees for the years 1924 and 1925 were as follows:

	Yields in 1924	Yields in 1925
Group 1—pruned, limbs tied	68.0 pounds ±10.0 pounds	119.2 pounds ± 8.8 pounds*
Group 2—pruned, not tied	8.5 pounds ± 2.7 pounds	34.7 pounds ± 5.1 pounds
Group 3—little pruned	35.2 pounds ± 6.7 pounds	105.0 pounds ±15.2 pounds

For the purpose of closer analysis of these results, trees in each group were ranked according to the total yield for the 2 year period and then divided into 3 lots each containing the same number of trees. The first lot was made up of trees having the highest yields; a second lot, of trees having the lowest yields, while the third lot contained the trees with medium crops. The highest yielding lot of the group of trees with tied limbs averaged 392 pounds to the tree, which was 4.5 times as much as the corresponding lot of the pruned, but non-tied group, and 2.1 times as much as the high yielding lot of trees of the little pruned group. The medium yielding lot of the tied trees average 153 pounds. This was 4.3 times as much as corresponding trees in the second group and 1.1 times as much as those in the third group. The low yielding trees with tied branches averaged 43.5 pounds— 2.2 times as much as the pruned, but only .8 as much as the little pruned trees.

In keeping with the published data of most pruning experiments with young trees, these results show that pruning—even moderate pruning—which tends to open the top, greatly reduces the yield as compared with the non-pruned trees. Bending or tying down the branches, however, has counteracted this influence of pruning and has caused the trees to yield about as much as, or more than, the non-pruned trees. In view of the behavior of the little pruned trees in which no effort was made to admit light to the tops, the good yields borne on the bent trees can not be ascribed entirely to the better exposure of the bearing wood to light. Observation of the bearing habit of the little pruned Northern Spy trees indicates that much of the earlier crops may be borne in the shady portion of the tree on wood which has such poor exposure that it would normally be regarded as unfit for fruit production. Light undoubtedly does have some favorable influence on fruiting and certainly it seems to increase the efficiency of the leaf surface. This is indicated by the fact that the heavier fruiting of the trees with tied branches was not accompanied by a slower increase in trunk circumference than shown

by other groups. The trees with tied down branches gained an average of 2.33 inches during the 2 year period, while the remaining trees increased about 2.05 inches during that time. The average increase in circumference for the two years preceding the experiment was 4.7 inches for the trees with tied limbs, and 4.8 inches for the others.

A few water sprouts grew on the bent branches near the trunk. The influences of geotropism and polarity on the new growth coming from the inclined branches was apparent. There is also the possibility that the bending caused some change in the movement of nutrients that influence the yields. Two hundred years ago, the explanation of the results that accompany bending of branches of fruit trees was embodied in the following rule, among others, given by Langley (1729) to those who would, "plainly discover their long riveted Ignorance,—if they but curb their superficial Imaginations, and cooly read, so as to perfectly understand—".

"The nearer Branches are laid to an horizontal Position the Velocity of the Sap is the more retarded, and the nearer to a perpendicular Position, the more freer; therefore Branches that are inclinable to Luxuriancy, may be checked by being nail'd horizontally; and those that are weak helped by being nail'd perpendicularly." As to just how much change in velocity of the sap there is we have no data.

Experiments with Kieffer Pears

The trial with the Kieffer pears was not as extensive as with the apple. Trees used in this experiment were 8 years old in the spring of 1924 when the limbs were first tied down. The original plan was to allow the limbs to bend naturally from their upright position as a result of the weight of fruit. While most of the trees had borne some fruit in previous years, the growth habit was still too upright in the majority of cases even in those which had been pruned to give them a spreading habit. In only a few trees and on scattering branches were the limbs bent by the crop.

The method used in bending the pear limbs was slightly different than that described for the apple. In the first place the limbs were only about 1 to 1½ inches in diameter at the point of attachment to the trunk, and there were more to the tree. The branches to be tied down were grouped into 3 or 4 lots each containing several branches originating on one side of the tree. The ends of these branches were pulled toward one another and tied together. Each bundle was then bent down toward the ground and held in place by binder twine fastened to the trunk. The branches thus bent were distinctly arched with the end of the limb lower than the middle portion. The tying was done about the time the buds opened in the spring. In a few months the branches had become fixed in the new position so that the twine could be cut.

Some of the trees with limbs tied down had a good crop of fruit which was held to maturity without the limbs breaking under the load. Similar trees in which the branches were bent during later

summer as a result of the heavy crop lost several limbs toward the end of the season. The limbs tied down in spring were evidently strengthened in some manner before the crop attained its weight. There was no appreciable difference in the thickness of the newly formed annual ring, nor in other histological features that could be observed by microscopic examination. A plausible explanation of the apparently greater strength of the limbs bent in the spring is that the current season's annual ring was laid down over the woody cylinder in its inclined position and hence was not under such great stress as the new wood on the limbs which were bent by the crop at the end of the season.

New shoot growth was produced on a number of the limbs that were bent in spring, and the spurs seemed to be in good condition for succeeding crops. The trees now have a desirable spreading habit and can be satisfactorily shaped with very little pruning. Similar shoot growth may take place during the coming season on the limbs bent naturally by the crop, but in the meantime at least one year will have been lost in shaping the trees. Furthermore in some cases many of the limbs bent by the crop will not remain permanently inclined, and some will break.

Summary

The results thus far obtained with the Northern Spy apple and with the Kieffer pear indicate that tying the branches so as to give them a more nearly horizontal position may be a means of saving several years in training upright trees to a more spreading habit without the necessity of severe pruning. Earlier fruiting is thereby induced and since inclining the limbs gives more favorable exposure to much of the leaf surface, such early fruiting does not necessarily dwarf the trees provided they are growing under good soil conditions Studies are still to be carried out with trees that have had no pruning and which are several years younger than those used in this test.

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An Experiment in Propagating Apple Trees on Their Own Roots

By E. C. AUCHTER, *University of Maryland, College Park, Md.*

INTRODUCTION

INDIVIDUAL trees in many of the large orchards throughout the Shenandoah-Cumberland Valley region often show great variability as to growth and yield. This can readily be noted even in orchards planted on well drained, level land, which seems to be uniform as regards texture, fertility, drainage and subsoil. Investigations of undesirable trees in such orchards show, in many cases, that the trouble is not due to either insects or diseases. The most logical conclusion in such cases is that the stock and scion are uncongenial. The two either do not unite readily at the graft, or if they do unite there may be very little free movement of mineral nutrients and elaborated foods. Then too, it is possible that some of the stocks which were used, varied as regards dwarfness.

As a result it can be seen that there might be a very high degree of variability as to growth and yield of trees growing under apparently uniform environmental conditions. Differences in tree growth may not be noticeable in some cases until the trees have borne 1 or 2 crops. Often tree growth seems satisfactory, but practically no yields are secured.

Shaw (7), Webber (8 and 9), Hatton (2 and 3) and others have also drawn attention to the importance of the root-stock problem, and Hatton and his co-workers, especially, (4 and 5) are making some very interesting and valuable root-stock studies.

Because of this high variability under apparent uniform conditions, it can be seen how the results of such studies as pruning experiments, cover crop experiments and orchard culture and fertilizer tests might be affected.

Batchelor and Reed (1) have emphasized the value of taking individual tree records for from 2 to 4 years before experimental plots are selected in an orchard. This would, no doubt, locate trees which were poor because of poor stocks as well as because of any normal soil variation.

STATEMENT OF PROBLEM AND LITERATURE REVIEW

When plans were made by the Horticultural Department of the University of Maryland to study the growth of young apple trees under different soil management and fertilizer treatments, it was decided to eliminate the error caused by the variability of unknown root stocks by first propagating on their own roots the trees to be used in the experiments. This was done by the long scion-short root, whip graft method.

This general method of propagating trees on their own roots has of course been used previously by both English and American investigators. Shaw (7), Moore (6) and Hatton, Amos and Witt (4),

especially, have published the results of their findings in the last 5 or 6 years. As might be expected, they found varieties to vary greatly in the readiness with which they sent out roots from scion and the variation was also great within the variety. Shaw apparently found several varieties that formed sufficient roots from the scion during the 2 years' growth in the nursery to support the transplanted tree after the seedling root had been removed. Although he states that the removal of the nurse root is a severe check to the young tree, especially with those varieties that do not root freely from the scion. In most cases he cut back the whips in the nursery to stubs following the first year's growth. Although Moore found several varieties to form roots from the scion, he states, "In no case have we observed a 2 year old nursery tree, grown under ordinary nursery conditions, possessing sufficient roots to sustain it when the stock roots were removed. Some 2 year old trees have been observed, but the percentage of trees of this age possessing any scion roots were very small and the roots were mostly fibrous and of small diameter." Hatton, Amos and Witt, in some preliminary experiments, did not have very good success in getting the scions to root in the case of "Nurse root" grafts.

Inasmuch as we in Maryland have had fairly satisfactory results in securing good own rooted trees for orchard planting after 2 years in the nursery, we thought that it might be worth while to explain our methods and results so that investigators, at least under similar conditions, would see how easy it was and would be encouraged to propagate their own trees on known roots before starting long time orchard field experiments.

Method of Propagation

Moore used scions from 2 to 6 inches in length, while Shaw's averaged from 6 to 8 inches long. Moore got best results with those 6 inches long. In Maryland, scions at least 16 inches long were used—some were 20 inches. A short piece of root (2 to 3 inches in length) was used. No especial care was taken in making the graft except to get the cambiums together along one side.

The grafts were then planted deep. Only the top bud of the scion was left above the surface of the ground. We hoped that conditions for growth of the seedling root, when it was planted so deep, would not be satisfactory. We thought if the seedling root could thus be checked some in growth, that more and better scion roots might then be developed, especially if soil conditions for growth of scion roots would be more favorable.

In the winter of 1921–22, 400 Stayman Winesap, 250 York Imperial and 100 Yellow Transparent grafts were made as described above. After storing in cool, moist sand until spring, these were planted deeply. With part of the grafts, furrows were first plowed out and then heavy spades were used to simply open a crack in the soil into which the graft was inserted. With others simply a deep hole was made with a crowbar and the graft planted. In all cases care was taken to get the soil packed tightly about the graft. The soil was a well drained, fertile clay loam.

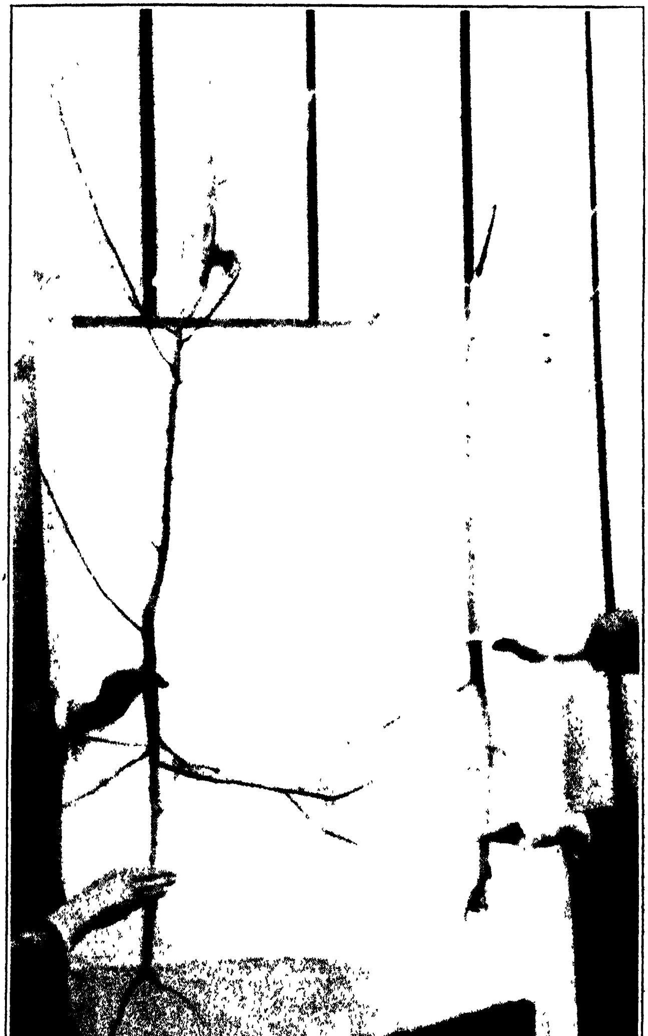

FIG. 1 Note the vigorous scion roots on these long scion-short root grafts. Scions were 20 inches long while the roots were 3 inches in length. As a result of deep planting, conditions for seedling root growth were apparently poor (note poor root growth below lower bands). Under such conditions vigorous root growth of Stayman Winesap occurs from the scion.

The grafts grew vigorously the first season (1922), and the whips were headed back to 28 inches in height at the beginning of the second season's growth. The trees also grew vigorously during the second season (1923). They were left in the nursery row and dug in March.

Results after Two Years in the Nursery—1922–1923

Of the 400 Stayman Winesap grafts, 300 had produced excellent roots from the scion, 50 had produced medium to poor roots, 25 had produced poor roots, and 25 had produced none whatever from the scion. The 300 grafts with excellent roots had from 5 to 8 large roots from each scion. These varied from the size of a pencil in thickness to three-fourths inch in diameter. In addition there were several smaller roots. The scion roots were from 2 to 14 inches beneath the surface of the ground. Most of them were between 4 and 9 inches deep. With these trees the seedling root had not made a vigorous growth. Two-hundred of these trees, after the seedling roots had been removed, were planted in an orchard for soil management and fertilizer tests, in the spring of 1924. They all grew excellently, and have continued to do so during 1925. We feel, from the results secured, that the extra labor and time required to plant these deeply, and later to dig them, was justified. The errors, due to unknown and variable root stocks and possible poor graft unions, have been practically eliminated in this long time experiment. The other 100 trees were located with various orchardists under different conditions, and have grown well. The 50 trees with medium to poor roots were planted, and are all alive, although they are not as vigorous as the others.

Of the 250 York Imperial grafts, 130 produced excellent scion roots, (although they were not as thick in diameter as the Stayman Winesap roots), 60 produced medium to poor roots, 25 produced poor roots, and 35 failed to produce any roots. The 130 trees with excellent roots were planted in an orchard after the seedling roots were removed and have grown well for 2 years. The 60 with medium to poor roots were planted and practically all have grown. Some of them are not of normal growth however.

Of the 100 Yellow Transparent grafts, 40 produced excellent roots, 30 medium to poor, 10 poor and 20 failed to produce any roots. The 40 trees with excellent roots have grown satisfactorily in an orchard. Even though certain grafts did not grow vigorously, they often rooted freely from the scion.

Grafts made in 1923

In the winter of 1923, additional long scion-short root grafts were made using the same length of scion and root as previously described. The 4 varieties: Wealthy, Delicious, Stayman Winesap and York Imperial were used in the test. After making the grafts, fine copper wires were twisted about part of them just above where the graft was made. It was felt that as the scions grew the wire might gradually girdle the seedling root. It was hoped that this might check the

growth of the seedling roots and encourage root formation from the scions. All grafts were planted deeply in a well drained, sandy loam soil during the spring of 1924. They grew here during the season of 1924 and 1925

Results Obtained

The grafts as a whole did not make as vigorous a top growth in this sandy loam soil as those planted in 1922 on the clay loam land. However, good two-year old trees were secured in most cases at the time of digging (December 15, 1925). Table I, shows the number of trees used and the percentages which formed good, medium, poor, or no roots.

Trees listed as having good roots, have from 4 to 7 roots, about the thickness of a lead pencil, growing from the scions. There is no question but that they will be able to support the tree satisfactorily after the seedling root is removed.

Those listed with medium roots have from 3 to 5 roots, but at least half of the roots formed are slightly less in diameter than a lead pencil. Based on our previous results these trees should make at least fair growth the first year in the orchard after the seedling root has been removed.

Those listed as having poor roots produced from 1 to 3 small roots It is quite certain that poor tree growth, if any, will result, after the seedling root is removed

A study of the Table I shows that the different varieties vary regarding the number of desirable roots produced from the scion. Delicious gave the best results, followed by Stayman Winesap, Wealthy and York Imperial The use of the copper wire did not give consistent results With Wealthy, a higher percentage of good roots was secured where the wire was used, but the total percentages of good and medium roots were approximately the same in both cases. With the Delicious, better results were secured without the wire. With Stayman Winesap very little difference could be seen, but with York Imperial the use of the wire was apparently beneficial

Stayman Winesap did not produce quite as high a percentage of good scion roots in this test as in the preceding experiment. The sandy soil was apparently not as desirable as the clay loam, however the season of 1925 was a very dry one, while that of 1923 was unusually wet. This increase of moisture was no doubt very beneficial also.

The interesting and valuable part of these results, however, is the fact that over one-half of the grafts produced scion roots in sufficient numbers to easily support the tree, after the seedling root is removed. This evidence, together with that found in the previous experiments, prove that under our conditions, at least, own rooted trees can easily be produced in large enough numbers, in 2 years for orchard experimental work.

Grafts Made in 1924

In the winter of 1924, 700 long scion-short root Stayman Winesap grafts were made and planted in the spring of 1925 on clay loam soil.

TABLE I—SHOWING THE NUMBER OF GRAFTS USED AND THE PERCENTAGES FORMING GOOD, MEDIUM, POOR, OR NO ROOTS FROM THE SCION

Nature of scion roots	Wealthy—No wire		Delicious—No wire		Stayman Winesap—No wire		York Imperial—No wire	
	Number of grafts	Per cent of total	Number of grafts	Per cent of total	Number of grafts	Per cent of total	Number of grafts	Per cent of total
Good	21	26.92	17	62.96	20	34.48	2	5.00
Medium	19	24.36	7	25.92	13	22.41	12	30.00
Poor	16	20.51	3	11.11	11	18.96	12	30.00
None	22	28.20	0	0.00	14	24.13	14	35.00
Total	78	—	27	—	58	—	40	—

	Wealthy—Wire		Delicious—Wire		Stayman Winesap—Wire		York Imperial—Wire	
Good	24	34.78	22	44.00	19	38.76	47	35.88
Medium	12	17.39	17	34.00	12	24.49	39	29.77
Poor	17	24.63	7	14.00	10	20.41	38	29.00
None	16	23.18	4	8.00	8	16.32	7	5.34
Total	69	—	50	—	49	—	131	—

Due to a very dry season these have not grown as well the first year as the grafts in the preceding experiments. However, it has been noted that even if certain grafts do not grow very well the first year, they usually do very good the second year Most of the scion roots are often formed during the second year in the nursery row. We confidently expect that these 700 grafts will produce at least 50 per cent of desirable own-rooted trees for orchard planting after 1 more year's growth in the nursery.

Root Cuttings as a Means of Propagating Own-Rooted Trees

Yerkes (10) results and the results of others show that after known roots have been secured by the long scion-short root method, desirable trees can be propagated on their own roots by root cuttings. Other varieties can be budded on these known plants if desired. Thus Grimes can be produced on Stayman Winesap roots, or vice-versa, if desired. Thus after trees are once secured on their own roots, it might be easier and more desirable to propagate future trees by root cuttings. By the use of both of these methods, or by mound layering, every investigator, at least, should be able to secure trees for experimental purposes with the variable (unknown root stocks) eliminated. The use of such trees should make many of our results secured in orchard experiments more reliable. Smaller differences could probably also be measured.

The problem is so important that much work will no doubt be done in the future relative to the value of the roots of many of our common varieties as stocks. In Australia and South Africa, trees on Northern Spy roots seem to be especially resistant to attacks of wooly aphis on the roots. In addition, selections will no doubt be made and propagated of various seedling stocks. The time will no doubt come when the demand will be great enough (the growers being willing to pay an increased price) so that nurseries will have to change their methods of propagating trees and produce trees either on their own roots, upon seedling roots of known parentage, or upon carefully selected, uniform strains of seedling roots

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The Propagation of Own Rooted Apple Stocks

By T. J. Maney, *Iowa State College, Ames, Iowa*

THAT great variability may exist in the production and growth of individual orchard trees under plot experimentation, has been shown by the statistical studies of Batchelor and Reed (2); Hedrick and Anthony (6); Anthony and Waring (1) and Sax and Gowen (14). In many instances this variability has been so large that it apparently has often obscured the value of any variation in yield which may have arisen from differences in plot treatments.

It is important to note that the most carefully planned fertilizer test with orchard trees in America, the New York Experiment Station (Geneva) Project, has a coefficient of variability of 23 per cent. At the Pennsylvania Station, the variation in its orchard fertilizer experiments is about 35 per cent. At the Maine Station, the records on 881 Ben Davis trees show that certain of them are of the productive type—strong, vigorous trees with a large head, and have averaged 283 pounds of fruit per year, while others of the unproductive type with upright slender branches have averaged 46 pounds per year. In an orchard soil cultural experiment at the Iowa Experiment Station, certain 32 year old Northwestern Greening trees of comparable size and vigor growing on a loess soil which is extremely uniform in texture, have shown a difference in production for a 13 year period of 8646 pounds for the high to 1293 pounds for the low producer. During the same period, the high producing tree made a circumference growth increase of 21½ inches while the low producer made a growth of 21$\frac{11}{16}$ inches. Practically the same relationship exists between several other trees in the experiment.

Of various factors including soil types, mechanical injuries, insect and disease infestation, cultural methods, and variable seedling root stock which may influence individual behavior, it is the general

concensus of opinion that the seedling root is probably the chief cause of variation among mature orchard trees, and that in order to smooth out individual differences we must first secure trees worked on uniform root stocks that are asexually propagated."

Since the inception of the horticultural work at the Iowa State College, the study of orchard stocks has been a major project. Budd (4) was a pioneer in this line and worked out the method generally adopted in the Upper Mississippi Valley of grafting long apple scions upon short seedling roots and planting them deep in order to induce rooting on the scions which, in most cases, are generally hardier than the variable seedling roots.

Attempts to employ this practice for obtaining trees on their own roots has resulted in only a small percentage of success. Shaw (12) reports success with this method, but does not indicate the degree to which rooting occurred on the scion. Moore (10) after examining a large number of two-year cut-back nursery trees, found only a small percentage well rooted on the scion. Practical experience has shown that grafted trees are hardier than budded trees, but the difference is the result of soil protection to the seedling or scion influence rather than the production of scion roots.

For years Australian growers have practiced grafting standard varieties on own rooted Northern Spy for the purpose of combating the American blight (wooly aphis) to which the Northern Spy is not susceptible. This variety is obtained on its own roots by stooling, layering and nurse graft methods. The latter method involves the use of a long scion, into the side of which, a seedling piece root is inserted. Roots develop on that portion of the scion which projects below the union. This method was tried in our work with Virginia crab* and Hibernal with practically no success. With Northern Spy, two-year cut-backs, when dug, 50 per cent had rooted well, but the majority of the trees were so badly infected with crown gall at the point of union with the nurse root that the practice cannot be considered efficient.

While conducting some graft union studies with a large list of hardy varieties in the greenhouse where raised benches, 14 inches in depth, were used, it was found that scion roots were produced near the surface where soil was more moist than that near the bottom of the bench. This led to a test with standard varieties grown in a ground bench, 16 inches deep, where the lower 8 inches was filled

*About 40 years ago, N. K. Fluke who was working for Suel Foster of Muscatine, Iowa, discovered mixed among Hewes Virginia Crab seedlings, the variety now known as the Virginia Crab. Mr. Fluke soon after this bought some land near Davenport, Iowa, and set out a good many grafted trees of this selected Virginia Crab type. The variety was disseminated extensively by Fluke and is now recognized as one of the leading stocks in the middle-west. It is a very hardy, vigorous growing tree, deep rooted and resistant in trunk and bark to the common fungous diseases. It makes a perfect union with practically every variety grafted upon it. The Virginia Crab, as now grown in the middle-west, is propagated by root grafting like any standard variety and is not a general line of miscellaneous seedlings as sometimes conceived by those not familiar with the history of its origin.

with washed sand and the upper with composted soil. The roots were plunged to the union in the sand while the scion was entirely in the soil. Dudley, McIntosh, Okabena and Northern Spy threw out strong scion roots in practically all cases, while Hibernal, Virginia crab, Fameuse, Ben Davis and Malinda, rooted strongly to the extent of about 50 per cent. Patten, Shields, Wealthy, Malinda, Grimes, Jonathan, Tolman, Red Siberian, Yellow Siberian and Whitney, were not induced to root.

During the progress of our crown gall studies with apple grafts, it was observed that Patten, which is a variety most difficult to root, when wrapped about the union with several layers of grafting string treated with Bordeaux mixture, was girdled by the string which was preserved from rotting. In these cases, scion roots were induced above the union to replace the stock root which at 3 years from planting was completely cut off. Micro-chemical tests on the tissue immediately above the girdle indicated a large accumulation of starch. Kraus and Kraybill (8) observed that parts of the stems of cuttings of tomato plants with a large amount of storage carbohydrates and particularly parts where such storage was localized when supplied with moisture, or moist conditions, produced roots abundantly. They suggested that this fact would be of particular interest in vegetative propagation. Starring (15) also found that rooting was induced by high carbohydrate content in cuttings of tomato and Tradescantia. Schrader (11) states that high carbohydrate content in tomato cuttings plus a relatively low supply of soluble nitrogen, favored the regeneration of roots.

Certain tests in which the graft union was wrapped with 2 turns of copper label wire were made. In 3 tests with Virginia crab 50, 73 and 76 per cent of well rooted trees were obtained. Two tests with Hibernal gave 40 and 74 per cent, while 2 tests with Dudley produced 78 and 100 per cent. With certain rather free rooting varieties like Virginia crab and Dudley, this method may have commercial possibilities and it is certainly valuable in obtaining a supply of own rooted trees for experimental purposes.

In 1923, an experiment in mound layering was conducted on a block of three-year old nursery stock which included 20 of our hardiest standard varieties. The stock had been cut back during the seasons of 1921 and 1922 so that a good stool had developed which was again cut back in the spring of 1923. The new shoots were allowed to grow to a height of 6 inches and were then mounded and additional soil was added 3 different times during the season to the mound, the final depth being about 12 inches. In the fall of 1923, it was necessary to remove the stock from the entire nursery and on examining the stools it was found that Dudley, Virginia, Hibernal and Northern Spy were rooted excellently. Dudley had good roots on 98 per cent of the stools which bore 4 to 10 strong shoots respectively: These rooted shoots were planted again in 1924 and redug during the past season. Invariably, they had developed excellent root systems and ranged in caliper from one-half to eleven-sixteenths inch. Wolf

River, McIntosh, Whitney, Okabena, Red Siberian and Yellow Siberian developed roots to the extent of about 20 per cent on the stools, while Malinda, Patten, Wealthy, Tolman, Peerless, Shields and Oldenburg were unrooted.

After the purchase of a new tract of land for the Pomology Section a new stock nursery was started during the spring of 1924. This planting, at the present time, contains about 300 varieties including seedling and standard sorts. In the spring of 1925, it was decided to try a different method of mound layering consisting in cutting back the one-year old grafts to about 12 inches, and removing a spadeful of dirt on one side of the graft which was then heeled over and covered to the tips with the dirt removed. This makes a very rapid method of procedure and is superior to stapling down the shoot with wire or twigs. The ends of the shoot were covered with loose soil to a depth of 1 to 2 inches through which the growing tips were easily forced. After the growth was 4 to 6 inches tall, loose dirt was raked up to them to a depth of about 4 inches. This was all the covering which was given throughout the season. The spring of 1925 was most unfavorable for growth as the first rain did not fall until June 1. The stock made only fair growth by the end of the season. Part of the mounded material was uncovered November 14 and the rooted shoots removed. The following table indicates the extent to which roots were formed.

ONE YEAR APPLE STOCKS LAID DOWN APRIL, 1925—EXAMINED NOVEMBER, 1925

Variety	Number laid down	Number well rooted shoots removed
Dudley	70	105
Haas	27	6
Glory of West	12	4
McIntosh	68	85
Northern Spy	35	72
Northwestern Greening	20	23
Red Siberian	42	23
Shields	15	1
Tolman	25	0
Vigorous Hardy Stock Unknown Variety	13	19
Virginia Crab	35	20
Whitney	18	17

This work is preliminary to a more extended trial of a method which appears more promising than simply mounding up the stool. It is planned to increase the number of stool shoots by heading back and then make a test in an extensive way.

The older horticultural writers have mentioned in connection with the propagation of dwarf apple stocks a condition which, at the present time, is known under the names of Burr-Knot, Gnarl and Goitre Gnarl. Knight (7) states that certain apple varieties with rough excrescences on the trunk and branches are always very readily propagated by cuttings. Loudon (9) also refers to its occurrence.

The writer has been familiar with the condition since 1914 when it was first called to his attention as an aerial form of crown gall.

Hatton (5) in his admirable work on the identification and classification of strains of Paradise apple stocks, refers to burr-knot and shows that it not only occurs on his 9 types of dwarf stocks, but also on certain selections of free and crab stocks. He says, "In the past any apple showing this tendency was recommended as a stock because the burr-knots indicated its readiness to root from layers or cuttings and it was supposed to indicate root vigor." Brown (3) has recognized that "Apple stem-tumor or burr-knots are not secondary outgrowths from crown gall tumor strands nor are they primary infections of the crown gall organism." Wolf (17) noted a condition similar to burr-knot on the fig and succeeded in rooting cuttings from wood on which the knots were present.

Recently, Swingle (16) has described burr-knot as he has observed it on certain standard varieties. He notes its connection with root formation and suggests its application in the propagation of apples from layers and cuttings.

Sorauer (13) who designates the condition as Goitre Gnarl describes the structure arrangement as follows, "The differentiation of the tissue of the spike of the gnarl takes place in the very first developmental stage inside the bark of the mother branch which at first appears to be only swollen. This swelling is produced from the upward forcing of the bark by a number of especially strongly developed medullary rays provided with meristematic tips. By the further apical growth of these structures, the bark of the mother branch is finally ruptured and the spikes of the gnarl covered with their own bark now appear as independent structures. But growth in length soon ends, since the bark cap and the underlying meristematic layer dry up. Instead of an apical growth, a basal lateral sprouting now takes place in the different gnarl spikes in the interior of the mother branch." He also states, "If we trace back the excrescent tissue which towards its base possesses a wood layer composed of slender reticulately thickened vascular cells passing over into the normal wood, it is found to be only a simple outgrowth of a medullary ray."

We have made sections of the burr-knots found on apple wood and find that the arrangement of the tissue and point of origin in medullary rays apparently holds true. In addition, it was observed that the tissue of the knot is heavily charged with starch again indicating the association of high carbohydrate content and free rooting.

In making observations on a large collection of cross bred apple seedlings, the occurrence of burr-knot was noted on several individuals. In one cross Ben Davis x Patten, 2 trees were severely affected. These trees were borne as seed in 1909 and planted in the orchard in 1914. At present they are approximately 16 feet in height, vigorous and hardy and resemble more in appearance the Patten than the Ben Davis. The knot formation appears on 5 year wood or older. To note if the trouble was transmissible, the bark of several healthy trees of various varieties was scarified and mascerated burr-knots were rubbed into the wounds. No infection took place. In 1915

buds from one of the trees, 5–10–29, were placed on two-year Virginia Crab, and as a topworked variety has developed very pronounced knots on the older portions. As a scion, it appears to have affected also the character of the bark on the trunk of the Virginia Crab, making it rougher than that commonly found on this variety. The union, however, is good.

In April, 1923, a branch stub 3 feet long and 2 inches in diameter with knots at the base, was cut from tree 5–10–29 and planted in the greenhouse. Growth started in about 2 weeks and by October, 1923, several terminal growths of over 3 feet in length had been produced. The root development was also excellent. Scion wood was also secured from the original tree and made into root grafts which were planted in the nursery. Scion rooting took place on all the grafts observed at the end of the first season. The rooting did not seem to be dependent on the presence of burr-knots, but took place at the base of each bud below the surface of the ground. In 1925, the one year grafts were cut back to 12 inches and laid down as previously described. Part of this lot was uncovered during the past season and from 33 layers, 75 well rooted shoots were taken. The growth of the shoots was equal to any of the standard varieties in the nursery.

Burr-knot was also observed in a lot of 4 year old cross bred apple seedlings. The most pronounced cases occurred on 4 seedlings in combinations of Northwestern Greening x Grimes and Grimes x Northwestern Greening. The seedlings in these crosses varied in height from 12 inches up to 7 feet and it was gratifying to note that the selected individuals averaged between 6 and 7 feet which was well above the average run of over 4000 seedlings in the block. These 4 trees were cut back for scion wood and then laid down in the nursery row in spring of 1924. In 1925, the new growth was cut back and mounded up. In November, 1925, well rooted, vigorous shoots were removed as follows: Tree 14862–1, 7 shoots; 14862–2, 12 shoots; 14923–1, 13 shoots; 14923–2, 27 shoots. The latter was the tallest tree in the seedling nursery measuring 7 feet from collar to tip of leader.

The behavior of these trees affected with burr-knot, which is undoubtedly a genetic factor, opens up a new line of investigation in the production of own rooted stocks. The burr-knot varieties root so readily from layers that the practice may have commercial application. If rooting from cuttings is as easy as indicated by the rooting of old wood and of scions above the union, the possibilities are greater.

Crown gall, the bane of nurserymen, is associated with grafted trees and whether it be caused by the organism Bacterium tumefaciens, or is the natural result of callus formation, which is questionable, the result is the same. The only logical control of the disease is to eliminate the point of infection, the graft union, and to substitute budding on roots of known vigor and hardiness.

The tendency of trees to burr-knot does not necessarily indicate dwarfishness. It is also associated with very vigorous growing trees of standard type. In hardiness, these trees seem to be comparable to

many of the hardy sorts and far superior to the average run of French seedlings. However, we must experiment further to note the rooting tendency of the shoot layers and also to determine the congeniality between the stocks and our standard varieties. It is usually misleading to predict subsequent behavior of trees by measurements made during the first year's growth in the nursery.

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Polarity in the Formation of Scion Roots.

By W. H. CHANDLER, *University of California, Berkeley, Calif.*

THERE is a large amount of experimental evidence that in root formation as well as in shoot growth the influence of polarity is such that root formation at the base of a plant tends to inhibit root formation above the base; and the working of the principle seems to be recognized in many of the special forms of layering. However, the work reported in this paper was suggested by the experience of McCallum* (1905) with bean cuttings; and that work only will be cited. When McCallum, by keeping moist a ring around a cutting above the base, caused root formations at that point first, those roots did not prevent root formation at the base when the base was later kept moist. However, when he caused root formation at the base first, roots would not usually form at a moistened ring above the base. In other words, roots at the base inhibited root formation above the base, but roots above the base did not inhibit root formation at the base.

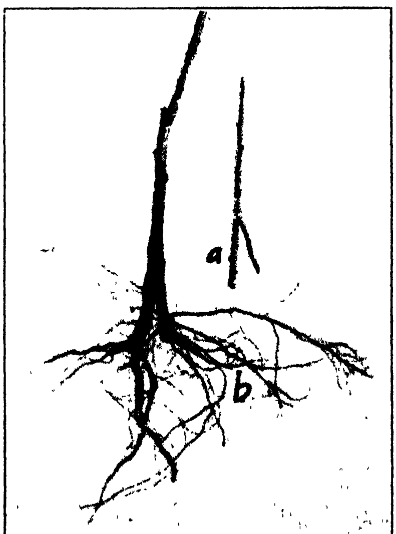

FIGURE 1.—Showing a bench graft made with a scion stub *a* extending below the union and (surrounding *b*) the root growth from such a stub at the end of the first growing season.

It seemed that if this were true with beans it might be true with fruit trees; and, in bench grafting, attaching the stock to the base of the scion might tend to reduce the number of roots to grow from the

*McCallum, W. B. Regeneration in Plants. I, II. Bot. Gaz. 40: 1905. 97–120, 241–63.

scion. In other words, the stock might tend to inhibit scion root formation.

In February, 1924, a few grafts of Chenango, of Northern Spy and of Smith Cider apple, and of Bartlett pear with apple roots, were made and planted in a tenacious adobe soil. Half of those grafts were made as whip grafts the stocks being attached to the bases of the scions. With the other half the stocks were attached about 2 inches above the bases. Thus a scion stub (*a* in Figure 1) projected about 2 inches below the union. If the stock should inhibit root formation above it on the scion then this stub might be in a more favorable position than the other part of the scion for scion root formation. With the first grafts of this kind made the common whip or tongue graft was used; but it is rather difficult to make a tongue graft on the side of a scion above the base. And so in making most of these grafts the top of the root piece was cut wedge shaped and this wedge was pushed up under a slit in the side of the scion.

FIGURE 2.—Showing at *a* thick short roots that start from a scion stub late in the growing season.

At the end of the first summer the trees were dug. With Northern Spy and Chenango apples nearly all scions with the stock attached a few inches above the base, had rooted on the stub below the attachment of the stock, most of the Northern Spy scions rooting early in summer and forming scion root systems like those shown at *b* in Figure 1, while with Chenango most of the scions seemed to begin to form roots late in summer and had thick short roots somewhat like those shown at *a* in Figure 2. With about half of the Smith

Cider grafts a few small thread like roots had formed on the stub projecting below the base of the union. No roots formed on Bartlett pear scions. With all the trees forming any scion roots the stock roots were all cut off, the tops cut back and the trees planted. Even those with the smallest roots made a fair growth in the following summer. With some, new roots grew also from stock tissue left; but the scion root system was always much the larger.

With none of these varieties did any roots form above the union either of common bench grafts or of grafts made with the unions a few inches above the bases of the scions, though the stocks were about 6 inches below the surface and the soil was kept moist. It seems that, probably due to the influence of the stock, conditions in a stub extending below the union are more favorable for scion root formation than conditions in the part of the scion above the union.

In the spring of 1925, more extensive trials were made. One hundred and fifty-five or more grafts of Northern Spy, 108 or more of Delicious, 92 or more of Jonathan, and 62 or more of McIntosh were made in each of 3 ways; with the stock at the base of the scion; with the stock attached about 2½ inches above the base; and with the stock attached about 5 inches above the base of the scion. The grafts were planted in a compact adobe soil at Berkeley, California, on April 14 and 15. They were planted between rows of young trees that were 10 feet apart each way. Conditions were thus not very favorable for the development of the grafts; and many died. With all varieties except Northern Spy the grafts with the stocks at the bases of the scions grew considerably better than those with the stocks attached above the bases. It is not possible to say whether this is due to the fact that the stocks were attached above the bases, or to the fact that these were wedge grafts, while those with the stocks attached at the bases of the scions were tongue grafts. The trees were dug November 26 and 27, 1925.

With Jonathan, of 121 grafts made with the scions projecting about 5 inches below the unions only 33 lived, and with only 3 did scion roots form on this scion stub; of 66 grafts made with the scions projecting about 2½ inches below the unions only 29 lived and with only 4 did roots form on this scion stub. However, with a few Jonathan trees there was a scion root system as good as that shown in Figure 1. With Northern Spy, of 259 grafts made with the scions extending about 5 inches below the unions 102 lived and with 30 roots formed on this scion stub; of 315 grafts made with the scion projecting about 2½ inches below the unions 156 lived and with 85 roots formed at the base of this scion stub. With Delicious, of 338 grafts made with the scions extending about 5 inches below the unions only 69 lived and with only 22 did roots form on this scion stub; of 140 grafts made with the scions extending about 2½ inches below the unions 47 lived and with 32 roots formed on this scion stub. With McIntosh, of 94 grafts made with the scions extending about 5 inches below the unions 26 lived and with 12 roots formed on this scion stub; of 63 grafts made with the scion extending about 2½ inches below the union 17 lived and with 10 roots formed on this scion stub.

With Northern Spy, Jonathan and McIntosh most of the scion roots that formed were long and rather slender like those shown at *b* in Figure 1, while with Delicious nearly all started later in autumn and were short, thick and white throughout most of their lengths like those shown in Figure 2, which is of a Delicious tree. Considering all the varieties, scion root formation was much better on scion stubs extending about 2½ inches below the unions than on longer stubs.

While the percentage of trees forming scion roots on these stubs is not large it is much larger than the percentage forming scion roots above the union. In fact of all the apple grafts planted only 4 formed any roots above the union. On the 478 trees that grew from grafts made with a scion stub extending below the union, 1461 scion roots formed on such stubs; while on these 478 trees and the 247 trees from grafts made with the stocks attached at the bases of the scions, only 22 scion roots formed above the unions. This suggests that the stock inhibits scion root formation above it.

It may be suggested that soil moisture conditions were more favorable for root formation at the base of the scions than nearer the surface of the soil. However, with some of the grafts made with the stocks attached at the bases of the scions, the scions were not cut entirely across and the tongues were started perhaps one-eighth of an inch above the bases of the scions. Thus there was sometimes a very slight projection of the scion below the union; and on this projection scion roots often formed. On the 247 trees from this form of bench graft 468 scions roots formed on such projections; while only 12 formed on scions above the union. It does not seem that moisture conditions could have been appreciably more favorable for root formation at such slight projections than 1 inch higher on the scion.

With most of the trees that formed long rather slender scion roots like those shown in Figure 1, most of the scion roots grew out of the callus at the base of the scion. This might suggest that it is the presence of a callus rather than polarity that favors scion root formation below the graft union. However, with many of the rooting stubs there was no callus; and, with those that formed the scion roots late in the season, as in Figure 2, more often than otherwise the scion roots were above the base at any position along the stub, but below the union. Nearly all the 485 Delicious scion roots were of this kind. Yet, with Delicious no scion root formed above the union. The evidence strongly suggests that there is polarity in scion root formation; and that the stock tends to inhibit, though not always to prevent, scion root formation above the union.

That the conditions in this planting were not especially favorable are indicated by the fact that so few scion roots formed above the unions. Perhaps more would have formed in the succeeding year. At the time the grafts were planted 783 cuttings of these varieties were planted, and none lived. However, while the soil conditions were somewhat unfavorable for the living of grafts and for scion rooting, the great length of the California growing season must have favored scion rooting. It is probable that in a section where cold

weather checked the growth early in autumn none of the roots like those shown in Figure 2 would have formed. At Ithaca, New York, on May 20, 1925, 16 to 25 grafts each of Northern Spy, Rhode Island Greening, Golden Delicious and McIntosh, were made with the scions projecting about 2½ inches below the unions and were planted in a rather compact wet soil. Dr. L. H. MacDaniels was kind enough to dig these and send them to me in the autumn of 1925. All of these as well as the grafts made in the ordinary way had made a very weak growth. And, while some stubs had large calluses, there were only 2 trees, both of Rhode Island Greening, that had each a very small scion root. It is possible that some of the stubs would have rooted in the second year. The trees, the scion stubs of which failed to root at Berkeley, are to be planted again to see if they will root in the second year.

A few grafts with scion stubs extending below the unions were made with a number of species of pears, with Ontario and Luken Honey peaches and with Marianna and Myrobalan plums. However, they were left in a warm place too long before planting and became so succulent that nearly all died, apparently from infection by an organism, within a few weeks after being planted. However, with all the Pineapple pear grafts that lived, strong roots formed on the scion bases. One *Pyrus ussuriensis*, one Ontario peach and one Luken Honey peach graft formed each a large mass of roots on the scion stub. With Old Home pear, of grafts that lived, there was a large callus at the base of each scion; but no roots.

With Marianna and Myrobalan plums a considerably larger percentage of grafts than of cuttings lived; and of the grafts that lived each had strong scion roots on the stub below the union, while only a few had scion roots above the union. These roots above the unions were small, apparently having started late, and were mainly at the bases of branches starting below the surface of the soil or on scions that were rather sharply bent under the soil. Thus with these varieties, which form scion roots very readily, the stock tends to inhibit, though not entirely to prevent, scion root formation above the union.

Summary

With bench grafts planted in the nursery, the stock tends to inhibit scion root formation above the union. This inhibition seems to decrease somewhat as the tree grows older. While, during the first year in the nursery, root formation is, with some of the varieties studied, much more abundant on a part of the scion extending below the union than on the part above the union, under the conditions of these trials root formation on such scion stubs was not sufficiently abundant to render propagation of trees on their own roots inexpensive. Scion parts extending 2½ inches or less below the union lived and rooted more satisfactorily than scion parts extending 5 inches below the union.

Vegetative Plant Propagation with Special Reference to Cuttings*

By P. W. Zimmerman, *University of Maryland, College Park, Md.*

Introductory

THE investigations reported in this paper were prompted by the fact that many of our valuable fruit plants, ornamental shrubs, and flowering plants, are hard to propagate. One acquaintance of the writer expressed the fact well when he asked the question, "Why are our most highly valued plants the most difficult to propagate?" He then referred to our fine hybrid rhododendrons, azaleas, lilacs, and to the blue spruce, all of which must be grafted on seedling stalks with considerable expense involved and often with a very low percentage of successful unions between stock and scion.

The present Federal quarantine which prevents further importation of these, and many other forms, from European countries, where they were grown at low cost, gives renewed interests in any investigations which might aid in propagation work.

In discussing the importance of propagating fruit trees by means of cuttings, Vierheller (1) says, "The Importance of this question is obvious when we consider the increased use of cuttings in propagation, and also the fact that hardiness, disease resistance, yield, growth habit, vigor, and perhaps quality of the fruit may be affected by the root. The great variability of seedling roots is common knowledge. It would be of immense value if this variability could be eliminated by producing trees on their own roots, without the expense of root grafting."

With numerous plant breeders constantly producing new forms which do not reproduce true to type from seeds, we shall be sure to have a growing interest in vegetative propagation. Some of this multiplication work will be done by budding or grafting, but since it is often impossible to find a congenial stock for the hybrid coins, propagation by cuttings will always hold a prominent place. It appears, too, that the seedling stocks are variable and sometimes modify the hybrid coin to such an extent that the breeder is unable to determine the exact value of his new production. Malloch (2) in his paper on "Asexual Propagation as an Aid to the Breeding of Root Stocks" makes an appeal for renewed efforts on the problem of rooting cuttings. He is quoted as follows:

"The breeding of improved types of rootstocks has not received the attention it deserves, owing partly to the increased difficulty and expense of conducting such investigations and partly to the less obvious value of such endeavors. The more thoroughgoing horticulturists recognize, however, the importance of the rootstock in its

*This paper is a partial report of work carried on last year at the Boyce Thompson Institute for Plant Research while the writer was on leave from the University of Maryland. The work is still being continued with the assistance of Mr. A. E. Hitchcock and Dr. Margery C. Carlson.

relation to soil conditions, to disease resistance, to uniformity of growth, and to the manner of union with the scion. In breeding for disease resistance it frequently happens that the resistance sought for resides in a distinct species. Such a species may or may not graft readily with the commercial type which it is desired to grow."

Swingle and Robinson (3), in discussing the importance of vegetative propagation, say, "Recently more attention has been given to vegetative propagation, particularly of fruit-tree stocks, in order to eliminate the variability so apparent in a lot of unselected seedlings. Aside from the commercial advantage of uniform stocks it is highly important in certain types of investigational work, particularly with fruit varieties, that great uniformity in the stock be secured to make the results of the experiments trustworthy. Not only do rooted cuttings insure uniformity of type and vigor, but where the improved methods recently developed are used practically a year's time can be saved in growing stocks to budding size, an advantage certainly sufficient to offset the additional trouble and expense of providing special equipment. Until recently it was deemed necessary for the best results that the rooting work should be carried on in a well-equipped greenhouse using steam coils to supply bottom heat."

In spite of the great importance of propagation by means of cuttings, no adequate investigations have as yet been reported concerning the underlying principles and factors involved. The mere fact that we have no such explanations is an indication that the problem is difficult. Curtis (4) found that when privet cuttings were treated with potassium permenganate they showed an increase in root growth and he offers 5 possible explanations for the stimulation. He is quoted as follows: "Five possible explanations for this stimulation have suggested themselves to the author. These are: (1) that the treatment causes a change in the nature of the food supply of the twig; (2) that it affects the rest period of the cuttings, serving to start growth earlier and thereby causing an apparent stimulation of root growth; (3) that it upsets the balance of food supply between the tops and the roots in favor of the latter; (4) that it retards or inhibits growth of microorganisms; (5) that it increases respiratory activity by catalytically hastening oxidation. The results obtained show that the last of these is the most probable explanation. The others may in some cases be of importance in explaining the rooting of cuttings, but the stimulation by potassium permanganate cannot be fully explained in such ways."

While these explanations are commendable, yet Curtis admits in the last two sentences quoted that he was unable to adequately explain the underlying principles. Adequate explanations, probably, are not to be forthcoming in the near future, but will await facts on anatomy, correlation, chemistry and stimulating agents.

The investigations reported in this paper were carried on to determine what some of the environmental factors are which operate while cuttings are striking root. It has been confined to such factors as (1) aeration, (2) medium, (3) age of the tissue, (4) leaves on cuttings

of green wood, (5) temperature, (6) place where basal cut should be made, (7) callus relations.

Aeration

In order to determine the distance under the surface of sandy loam where aeration is best for root growth in cuttings, specimens were placed at varying depth to 2 feet deep, expecting that growth might be uniformly more abundant at a certain point below the surface. The results are as follows:

Blue plum (Prunus domestica)—Roots appeared at the basal end only, approximately 2 feet below the surface of the soil.

Sour cherry (Prunus cerasus)—Rooted at basal end only, approximately 18 inches under surface of the soil.

Rhodotypus sp. and Weigela sp.—Rooted only at the basal end to a depth of 2 feet.

Lonicera sp., Philadelphus sp., Salix, and black currant—Roots appeared all along the stem to a depth of 2 feet. In black currant there was some tendency toward an increased growth near the surface. In other forms strongest roots appeared near the basal end.

These cuttings were made and set during the first week in November and left until the following July when the data were taken.

If good aeration were as important as we have been led to believe, it would seem that cuttings which root easily anywhere along the stem would root best and perhaps only near the surface. On the other hand, most forms rooted abundantly at the base, and some at the base only. In fact the plum did not root in numerous other trials under supposedly favorable greenhouse conditions.

In another experiment Salix cuttings were exposed in closed glass tubes to varying mixtures of carbon dioxide, oxygen, and nitrogen which were changed daily. No rooting occurs when 90 to 100 per cent oxygen is used. Best growth is had where 15 to 33⅓ per cent oxygen is mixed with 85 to 66⅔ per cent nitrogen respectively. Nearly normal growth occurs with 25 per cent carbon dioxide present if the oxygen remains 25 to 33⅓ per cent. With 12 per cent carbon dioxide, 25 per cent oxygen, and 63 per cent nitrogen, normal root growth occurs.

Rooting Medium

Sand has long been the standard rooting medium for cuttings and will doubtless always remain so. There is, however, some indication that other media may be preferable to sand for some forms. The genus Ilex, for example, responds quicker in peat moss (PH 3.6 to 4.5) than in sand. Delaware grapes root a higher percentage in peat moss than in sand, and they continue to grow throughout the summer in pure peat. The same is true for the hollies.

Some species of Viburnum which normally root only near the cut surface when planted in sand will strike root all along the stem when planted in pure peat moss. There seem to be some stimulating elements in the peat moss which do not occur in sand. By mixing peat moss and sand one should be able to find a medium especially good for

some forms. Such mixtures hold water better than pure sand and some benefit might be derived from the presence of the acid peat.

Age of the Tissue

Growing shoots of Weigela or canes of American pillar rose cut into 3 inch pieces and planted in series from tip to base show that 1 cutting responds more readily than the others. In some cases, for example, number 5 from the tip roots abundantly in 3 weeks, while numbers 4 or 6 on either side root weakly, and the others do not respond at all. The piece which responds first is not always number 5, but varies with the rate of growth and season of the year. In a slow growing root the piece most likely to respond first is near the tip.

Chemical storage and cell structure are probably the factors concerned in quick growth in green wood cuttings. That is, at a certain point on the stem cells have not yet become greatly lignified but are past the soft stage, and food storage is great enough to supply the needs until the leaves become active.

Cuttings of Prunus tomentosa root well if taken between May 15 and June 1, but root poorly toward fall. After December 20 the cuttings rarely strike root. This plant is coming to be popular both as an ornamental shrub and a susbtitute for sour cherry. With propagation as easy as indicated above, it should spread rapidly throughout the country.

Viburnum americanum is another form which roots with difficulty from hard winter wood, but with ease from early summer wood.

Among the conifers, hemlock (Tsuga canadensis) differs from most others in that the spring growth when used as cuttings on June 1 will strike root in 6 weeks, while the ripened wood taken in winter rarely roots. Blue spruce, on the other hand, will root from mature wood in winter, but not from spring growth in June.

Differing from the forms just mentioned are apple, peach and holly varieties. Apple varieties which root from cuttings do so from 2 or 3 year old wood as well as current growth. In fact 2 year old wood is apt to form stronger roots than terminals of current year growth. Peaches and hollies respond in a similar way.

Leaves on Green Cuttings

Where wilting can be prevented, the larger the leaf area on green wood cuttings the quicker the root growth. As mentioned above, cuttings of Prunus tomentosa taken May 15 root well when they keep a generous supply of leaves. On the other hand, when the leaves are removed the cuttings do not root.

Summer growth of Dorothy Perkins rose when made into cuttings strike root in 3 weeks if they are allowed to keep leaves. If leaves are removed rooting does not occur until the young buds have had time to force out new shoots to take the place of leaves removed.

Temperature

In order to determine whether or not specific temperatures could force root growth on cuttings taken from difficult forms, hundreds of

tests were made in constant temperatures ranging from 0°C to 32°C. Apples, plums and cherries which did not respond under other conditions did not respond to any constant temperatures. In any forms where rooting did occur, the time required varied with the temperature. For example, Late Crawford peaches strike root in 18 days at 24°C while at 20°C, 25 days are required and at 15°C, 40 days are required. Ilex verticillata roots in 18 days at 27°C; in 21 days at 24°C; in 28 days at 20°C; and in 42 days at 15°C.

It is very likely that forms which will root but are difficult to handle would be greatly benefited by certain definite temperatures.

Callus Relations

Generally roots do not arise from newly formed callus. The power to form callus differs greatly with different forms. Apples, cherries and blue plums which are amongst the most difficult to root from cuttings, form callus abundantly. A cherry stem of three-sixteenths inch diameter can form a callus growth ½ inch or more in diameter in 8 weeks. The structure of a callus growth is very much like that of a stem excepting for the epidermis. In its early stages the fluffy white growth on the surface is made by continuous cell division of the outermost cells. Upon exposure to the air these collapse readily and the surface becomes brown. Wood and phloem tissue follow a short distance under the surface and in time the wound is completely healed. When the tissue is differentiated as described it can give rise to new roots. In cherries often the new root appears at least ½ inch from the nearest point of the stem. In such cases adventitious roots must arise from the callus but generally, in most forms, they come through the bark above the callus.

General

Varieties and species show great variations in root growth from cuttings. Apples, for example, vary from 100 per cent root growth in cuttings to practically no response. Between these 2 extremes is the Sweet Bough with 40 to 50 per cent of the cuttings forming roots. C. F. Swingle (5) mentions a great varietal difference in apples toward tendency to form burr-knots, and states that roots arise from burr-knots when such parts are included in cuttings. Where such great differences appear it seems that one should be able to find something of the underlying causes. So far microchemical analyses have not proven of any value in drawing conclusions. Studies in chemical stimulation, anatomical structure, and microchemistry should be fruitful. Such work is now under way at the Boyce Thompson Institute for Plant Research and at the University of Maryland.

Adventitious roots appear with great regularity about certain regions on the stem. In weeping willow, for example, the new roots make a diamond shaped figure about the buds. In quince the new roots appear with regularity just above the buds. In clematis the roots form easier between two nodes than at the node. All variations can be found. Microchemistry should prove valuable when response is localized.

Van der Lek (6) has found what he believes to be morphological stem born roots in Salix and other forms. These, he states, appear normally on stems. The microphotographs which his publication carries show considerable differentiation at certain points and give the impression that these are new roots almost ready to merge. Whether they appear normally in this condition, or whether they had first to get a stimulus to make such growth, is a question. The writer believes that certain points contain cells which respond much more readily than other cells, but is not ready to call them "stem born root germs." The regularity with which adventitious roots appear about nodes seems to indicate that either food storage or cell structure, or both, are important.

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The Use of Burr-knots in the Vegetative Propagation of Apple Varieties

By CHARLES F. SWINGLE, *United States Department of Agriculture, Washington, D. C.*

IN THE Journal of Heredity for September, 1925, and in Science for December 11, 1925, the writer has called attention to the phenomenon of burr-knots on apple trees, and has pointed out their use in vegetative propagation. Burr-knots are generally not the hairy-root form of crown gall, as has so long been thought in this country. They are swellings characterized by the presence of root primordia, and their occurrence is a normal characteristic of some apple varieties. These root primordia are easily forced into growth and their use is common in horticultural propagation. This is contrary to the generally accepted idea that roots are initiated usually only after the special propagating conditions have been brought into action.

In the numerous rooting experiments of the writer, wood of various

ages from 1 month to 5 years was used for cuttings, but with only a few exceptions no roots were obtained except from such cuttings, and then only from such particular spots on the cuttings, as showed at the beginning external indications of the presence of root primordia. The time of making the cuttings, the medium used, temperature, light, humidity, etc., all probably play a part in determining the final result, but by far the most important condition for the production of vigorous roots seems to be the presence of definite root primordia in the original cutting. This type of apple propagation was mentioned by Knight (1) as long ago as 1809, and more recently by Duplessix (2) and by Hatton (3). The hearsay evidence presented by Duplessix includes no mention of burr-knots, but Knight and Hatton mention the presence of such swellings as a necessary prerequisite for rooting. In the few reported instances of cutting propagation of the apple in the United States, it seems probable that burr-knots generally were present, and that new roots arose from preformed primordia in the swellings now called burr-knots. Little light can as yet be thrown on the propagation by cuttings of such varieties as Delicious, Tolman, and Stayman Winesap, which form burr-knots only rarely if at all. It is clear, however, that varieties which normally produce many burr-knots, such as Buckskin, Springdale, Northern Spy and Esopus, may be expected to be capable of easy propagation through the employment of hardwood cuttings containing burr-knots. Such material has been used in this way, though only unknowingly by American horticulturists.

Burr-knots, although they constitute a varietal characteristic among apples, resemble fruit buds in their distribution on stems and branches; the older the tree is, the younger is the wood on which the knots appear. Their occurrence may be correlated with the local presence of an abundance of elaborated food. Knots are most often found in the vicinity of buds and at the bases of branches, where downward movement of elaborated food may be interfered with. Also, they are generally most numerous on the west side of the tree, where food should be more plentiful than in other regions.

Histological studies recently carried out show that burr-knots are in a close relation to the vascular (medullary) rays, and to the leaf and branch traces of the bud. These rays and traces provide a ready path for the translocation of sugars, etc., between the outer regions of the stem and the water-conducting and food-storage regions of the xylem and pith, a consideration that may explain the occurrence of burr-knot root primordia mainly close to the rays. This placing of the dormant primordia in the apple appears to be similar to the placing of the inconspicuous dormant roots in poplar, willow and currant stems, which have been studied by van der Lek (4) and reported by him in his recent and important article on root formation in woody cuttings.

Priestly and Ewing (5) have observed for some annual plants a correlation between adventitious root formation and the occurrence of a functional endodermis brought about through etiolation. This may possibly suggest what happens in the layering of apples, for etiolation may be presumed to occur in the part of the stem below

ground. But most of the roots on layers appear in the vicinity of buds, and the writer has been unable to observe thickened endodermis in any of the apple stems examined. In the case of burr-knots, however, the endodermis theory seems to fail entirely. Burr-knots arise on stems without any characteristic of etiolation and without any thickened endodermis.

In order to throw some light on what effect food supply may have upon the formation and development of roots, chemical analyses were made in September and October of this year of the stems of mound-layered, seedling apples. The stools to which these layers were attached were 3 years old, but the shoots had been removed each year so that the stems used were of only one year's growth. All shoots were mounded up in May, about 6 inches of each shoot being inside the mound. Part of those from each stool were completely defoliated in June and kept defoliated throughout the balance of the summer. The analyses showed little difference between shoots defoliated in June and shoots with all leaves left intact, in regard to the relative proportions of moisture, sugars, starch, pentosans, phloridzin, tannins, and combined nitrogen. However, there was a striking difference in the total amount of top growth and root development in favor of the shoots not defoliated. It appears as though root development depended in some way upon top growth, not upon the supply of any of these plant foods as indicated by the analyses.

Plett (6) and van der Lek have considered the possibility of a hormone action of the bud upon the differentiation and development of roots, and have concluded that some root-developing hormone must be formed by the green shoots. The writer has observed some facts which would indicate that such a hormone hypothesis may be valuable, but the experimentation has not yet gone far enough to warrant a discussion of this question.

The writer wishes to express his appreciation to Prof. Burton E. Livingston, and to Prof. Duncan S. Johnson, of the Johns Hopkins University, for many helpful suggestions and for the needed equipment for the studies here partially reported.

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Further Evidence of Uncongeniality in Disease-Resistant Stocks

By J. A. McCLINTOCK, *Tennessee Agricultural Experiment Station, Knoxville, Tenn.*

DURING the past summer at the Knoxville Station both peach trees and Marianna plum trees on their own roots, set in holes from which dying trees were removed in 1924, have made a vigorous healthy growth. This indicates that the fungus associated with dying or dead plum roots in 1924, is not sufficiently parasitic to attack well nourished plum and peach roots.

Five additional Elberta peach trees on Marianna plum roots, set in the spring of 1923, were dying or dead by the fall of 1925. These trees were dug and cultures made from the roots to determine the presence of fungi. In all 5 cases the plum roots and stock up to the union were dead, but in 3 of the trees peach roots had developed above the union. These peach roots were alive and apparently healthy, though not sufficiently extensive in growth to nourish the tops which had developed before the plum roots had died. Even though scion roots did develop sufficiently to care for the needs of the tree, such roots would not prove satisfactory because in nematode infested soil they would become infested the same as peaches on seedling peach roots. The enlargement of the peach trunks above the points of union in each case, and the death of the plum stock up to the point of union, furnishes additional proof of lack of congeniality.

In the tests of Elberta peaches on Marianna plum stocks at the West Tennessee Substation, several trees 3 years of age died during the past summer. In 1 case the tree had nearly matured more than 50 fruits when it suddenly wilted and died with the shriveled fruits still clinging to the branches. On digging these trees enlargements of the peach trunks were observed at the union with the plum stocks, thus indicating incompatible union as the cause of death.

Ten varieties of peaches dormant budded on Marianna plums, and on seedling peach stocks in 1924, were grown side by side throughout the summer of 1925. By the first of July the leaves of the peaches on plum stocks were yellowish, sickly, and retarded in growth as compared with the same varieties on peach stocks. Within the next 2 months a number of peach trees on plum stocks died while all of the trees on peach roots remained healthy and continued growth. Examination of the trees from time to time disclosed that in practically all varieties the peach tree trunks were enlarged just above the point of union with the plum stocks, thus indicating that elaborated foods were being stored there instead of passing back to the roots. A number of the dying and dead trees were dug, washed free from soil and examined. Sections of roots from a number of these young trees were planted and it was found that in only part of the dead trees was the fungus present which was found associated with dead trees in 1924.

Trees of several varieties of peaches budded on Marianna plum roots were cut longitudinally through the union, and in all cases a good physical union appeared to be established. Several varieties of plums budded on Marianna plum roots in the summer of 1924 have made good growth in 1925, and appear to have established congenial unions.

This incompatibility of a number of peach varieties for Marianna plum stocks limits the practical use of this disease resistant stock in the propagation of peaches. Tests are now being conducted to determine if this uncongeniality can be overcome even in an experimental way through the use of intermediate mutually congenial stocks.

The Effect of the Method of Sampling on the Results of Chemical Analyses of Horticultural Plants

By WARREN P. TUFTS, *University Farm, Davis, Calif.*

TWO YEARS ago in starting a series of chemical analyses of one-year old peach wood, a decision had to be made as to whether or not samples of this material should be separated on the basis of bark and wood, or distal and basal portions of the shoots. On account of previous investigations, and of those reported by Proebsting* with apple tree tissue, it was decided to separate the bark from the wood rather than the tip from the base, it seeming impractical, in view of the number of analyses contemplated, to make both divisions.

In analyzing the data thus secured it seemed advisable to make a further study of certain factors which might enter into the accuracy of the results obtained. A vigorous eight-year old Elberta peach tree which had been grown without irrigation was selected. Collections of material consisting of approximately 200 shoots each were made between 8:00 and 8:30 a. m., on 5 days beginning with July 27, 1925, and ending August 7, 1925, thus covering a period of 12 days. At the time these collections were made the tree had ceased vigorous vegetative growth. The shoots selected varied from 26 to 36 inches in length and were well distributed over the tree. It is thought that the sampling of the tree was uniform and adequate. These samples were designed to secure information on the following points:

1. What fluctuation, if any, is there from day to day in the chemical composition of one-year shoots of the peach?
2. What differences, if any, exist between terminal and basal bark, and terminal and basal wood?
3. Can total nitrogen be as accurately determined from dried as from fresh material?

The data concerning these points are presented in Table I. All figures are the average of at least 2 separate determinations. The

*Proebsting, E. L.—A relation of stored food to cambial activity in the apple. Hilgardia, Vol. I., No. 5, pp. 81-106, June, 1925.

TABLE I—ANALYSES OF ELBERTA PEACH SHOOTS

Date 1925	Portion of shoot analyzed	Per cent dry weight	Per cent total nitrogen on dry basis from analysis of green material	Per cent total nitrogen on dry basis from analysis of dried material	Mg. amino nitrogen per c.c. of expressed sap	Free reducing substance	Total sugars	Starch as dextrose
July 27	Bark terminal	37.8	1.75	1.74	1.21	1.89	4.82	9.68
	Bark base	40.4	1.30	1.25	.48	2.03	4.81	9.93
	Wood terminal	47.2	1.05	1.11	1.38	1.20	2.02	5.93
	Wood base	57.3	.46	.44	.50	1.04	1.34	5.64
July 29	Bark terminal	37.2	1.75	1.66	1.03	1.84	4.59	9.10
	Bark base	38.9	1.21	1.28	.47	2.03	4.63	9.73
	Wood terminal	46.4	1.02	1.02	1.16	.97	1.71	6.21
	Wood base	53.3	.41	.43	.40	1.06	1.48	5.33
August 3	Bark terminal	37.0	1.89	1.81	1.10	1.62	4.56	9.83
	Bark base	36.6	1.30	1.31	.38	1.96	4.76	10.12
	Wood terminal	45.5	1.24	1.15	1.11	1.14	1.92	5.93
	Wood base	55.3	.42	.46	.43	.90	1.29	5.54
August 5	Bark terminal	36.6	1.82	1.81	1.09	2.09	4.25	10.22
	Bark base	37.8	1.25	1.27	.42	2.03	4.61	10.70
	Wood terminal	44.2	1.25	1.29	1.23	.97	1.76	6.72
	Wood base	54.1	.46	.44	.47	.93	1.37	6.07
August 7	Bark terminal	37.5	1.88	1.83	.83	2.54	5.14	10.70
	Bark base	38.3	1.29	1.27	.38	2.30	4.62	10.78
	Wood terminal	49.5	1.05	1.12	1.83	1.12	1.90	7.10
	Wood base	55 7	.43	.37	.50	.90	1.39	6.44

total nitrogen was determined by the phenol-sulphuric modification of the Kjedahl method; the free reducing substances, total sugars and starch by the Munson-Walker method using the Shaffer-Hartman iodometric titration, and the amino nitrogen using a Van Slyke apparatus, from plant sap expressed from frozen fresh material at a pressure of 25 tons.

It will be seen from a study of these data that under the conditions of sampling above noted the following points are determined:—

1. The total nitrogen content does not vary greatly from day to day.

2. The amino nitrogen is somewhat more variable than total nitrogen content.

3. The three carbohydrate fractions, for which determinations were made fluctuate daily to a certain extent, such fluctuations tending to approach in magnitude those differences existing between base and tip, but in no case approaching the differences existing between bark and wood.

4. The greatest differences between tip and base are exhibited by amino nitrogen followed in turn by total nitrogen, total reducing substances in the wood, and starches in the wood. There is apparently little significant difference between the tip and base bark so far as these carbohydrate fractions are concerned.

5. The data clearly show that total nitrogen can be determined with equal facility from either fresh or dried material.

6. The amino nitrogen content exhibits no significant difference between bark and wood.

TABLE II—A STUDY OF THE RELATION OF BARK TO WOOD IN ONE-YEAR OLD SHOOTS OF THE ELBERTA PEACH, OCTOBER, 1925

Length of shoots in inches	Bark		Wood		Ratio of base to tip		Ratio of bark to wood	
	Tip Average dry weight in grams	Base Average dry weight in grams	Tip Average dry weight in grams	Base Average dry weight in grams	Bark	Wood	Tip	Base
6	.078	.085	.038	.080	1.09	2.11	2.05	1.06
12	.205	.254	.121	.270	1.24	2.23	1.69	.94
18	.369	.462	.294	.659	1.25	2.35	1.26	.70
24	.562	.792	.491	1 626	1.41	3.31	1.14	.49
30	.866	1.374	.812	2.745	1.59	3.38	1.07	.50
36	.989	1.651	1.150	3.465	1.67	3.02	.86	.48
42	1.455	2.184	1.664	5.542	1.50	3.36	.87	.39

Considering free reducing substances, total sugars, starch, amino nitrogen and total nitrogen as representative analytical fractions, it would seem from the data submitted that the separation of wood and bark is in most instances of more importance in localizing the presence of various plant substances than is the division of the same material on the basis of terminal and basal growth. Only in the case of amino nitrogen were the differences between terminal and basal portions greater than those existing between wood and bark.

In addition it should perhaps be emphasized that the bark contains much higher percentages of certain substances than does the wood. Furthermore in the bark the percentages of these substances are about as great at the base as at the tip. In view of the fact that the proportion of bark to wood is greater toward the tip than toward the base, it would appear that where samples are taken without the separation of wood and bark that the greater percentage of certain substances toward the tip may be due to a greater percentage of bark, rather than to a greater concentration of these substances in the living cells near the tip than in the living cells near the base.

I realize the difficulties and limitations of chemical analyses of plant tissues due to inexact methods and lack of knowledge of the constituents of a given material, nevertheless, I feel that the horticultural worker may well give careful consideration to his methods of sampling and refine his collections so that the data collected will be as definite and exact as is consistent with the chemical methods available.

In this connection the figures presented in Table II are interesting. Ten peach shoots each of the exact lengths specified were selected, cut into halves, the bark carefully separated from the wood and all samples brought to a constant weight. It will be noted that in both the case of the bark and the wood that the basal half contains more dry material than the terminal half. However, the fact that except in the longest shoots (36 and 42 inches), the dry weight of the terminal bark is heavier than that of the terminal wood is quite striking. This is not so in the case of apple and pear as shown in Tables III and IV, however, with these species the shoots were all quite long (36 to 48 inches) and the material was collected 2 months later in the growing season.

Tables III and IV present data for the apple (White Astrachan) and pear (Bartlett) somewhat similar in nature to that already presented for the peach in Table I. These samples consisted of from 15 to 20 shoots (36 to 48 inches) taken from a single vigorous four-year old tree. These shoots were each divided according to length into thirds.

It will be seen that in the case of the apple there is no significant difference in composition (of the fractions determined) except in total nitrogen, between different parts of the shoot when bark alone is considered. There is, however, a gradual decrease from tip to base in the storage of both reducing substances and starch in the wood. In the case of total nitrogen, larger differences seem to occur in the bark rather than in the wood, there being a gradual decrease from tip to base. The differences in all substances between the various portions, so far as location up and down the shoot is concerned, however, do not equal those existing between bark and wood in the same portions, this being particularly true with the reducing substances.

Likewise, in the case of the pear, there is probably no significant difference in the composition of the bark (of the fractions determined), except total nitrogen, in the different portions, however, there is a marked difference when bark and wood are compared.

TABLE III—CERTAIN ANALYSES OF ONE-YEAR OLD WHITE ASTRACHAN APPLE SHOOTS, OCTOBER 22, 1925

	Dry weight in grams	Per cent of dry weight	Free reducing substances	Total sugars	Starch as dextrose	Total nitrogen
Terminal third—Bark	25.4	49.5	2.32	4.18	15.52	1.197
Wood	60.1	68.9	.88	1.48	12.73	.537
Middle third—Bark	30.5	45.2	2.07	4.24	16.21	1.126
Wood	88.1	56.3	.65	1.02	9.88	.434
Basal third—Bark	40.0	48.0	2.13	4.36	16.40	1.084
Wood	179.2	63.0	.56	.78	8.40	.501

TABLE IV—CERTAIN ANALYSES OF ONE-YEAR OLD BARTLETT PEAR SHOOTS, OCTOBER 22, 1925

	Dry weight in grams	Per cent of dry weight	Free reducing substances	Total sugars	Starch as dextrose	Total nitrogen
Terminal third—Bark	38.5	43.4	1.77	3.63	16.11	1.080
Wood	52.5	57.9	.70	1.31	16.28	.644
Middle third—Bark	44.3	43.3	1.67	3.62	16.23	.900
Wood	89.3	56.0	.70	1.30	14.65	.470
Basal third—Bark	54.0	45.4	1.62	3.59	16.17	.853
Wood	132.6	56.5	.57	1.05	12.70	.490

Some Factors Influencing the Production of Peaches in the South

By J. R. Cooper, *University of Arkansas, Fayetteville, Ark.*

THE work on which the following observations and data are based was begun in 1920 in a 100 acre peach orchard about 7 years old, located at Lamar, in Johnson County, Arkansas.

The orchard is on rolling land with a soil ranging from Hanceville sandy loam to Hanceville fine sandy loam, which is considered one of our best peach soils. We have long known that these soils are rather low in nitrogen and they have been supposed to be deficient in phosphorus and potassium.

The experiments were laid out in 2 blocks, each containing a complete series of fertilizer plots of 8 trees each separated by buffer rows with every fifth plot a check. These 2 blocks were about 20 rods apart.

There was no crop in either 1920 or 1921, due to late frosts in 1920 and a freeze in the spring of 1921. Unfortunately, the 2 end checks in each block received nitrate of soda in 1923 which compelled us to discard them after that time.

TABLE I—The Effect of Different Fertilizer Elements on Yield, Terminal Growth, and Trunk Growth of Peach Trees

	Combinations containing P.	Combinations containing no P.	Average gain or loss	0	Odds
A.	1.6567±.1817	1.6756±.1828	.0181	.7168	1.84:1
B.	6.2854±.3200	6.4961±.3813	.2107	2.5875	2.3:1
C.	1.0286±.0860	.9878±.0837	—.0471	.4803	2.3:1
	Combinations containing K.	Combinations containing no K.			
A.	2.1150±.2366	2.2100±.2223	.0950	.7209	1.98:1
B.	6.4859±.6001	6.0795±.5168	—.4064	2.1365	4.1:1
C.	1.0154±.0905	1.0011±.0784	—.0143	.5082	2.3:1
	Combinations containing N.	Combinations containing no N.			
A.	2.6370±.1017	.6980±.0546	—1.9380	.7126	9999:1
B.	8.0011±.6894	4.6411±.3253	—3.3600	4.0615	9999:1
C.	1.2314±.0765	.7136±.0711	—.5178	.4808	9999:1
	No Fertilizer	Nitrogen only			
A.	.7650±.3811	2.6400± .1679	1.8750	.9119	2059:1
B.	3.8463±.4449	9.1750±1.6448	5.3288	5.4380	54.6:1
C.	.7900±.1623	1.4163± .1420	.6263	.4060	421:1

*A.—Yield in bushels per tree.
'B.—Terminal growth in inches.
'C.—Increase in circumference of trunk in inches.
*1922-3.
'1920-3.

A record was kept of the terminal growth and increase in circumference of trunk and, beginning with 1922, of the yield of each tree. A comparative study was made of the performance of terminal growth

TABLE II—NUMBER OF FRUIT BUDS FORMED ON ELBERTA PEACH SHOOTS OF DIFFERENT LENGTHS

	Number measurements			Number of buds			Average buds per shoot		
	Ck.	N.	P.N.K.	Check	O-N-O	P.N.K.	Check	O-N-O	P.N.K.
1 inch	86	184	185	516	1163	1146	6.00	6.32	6.27
2 inches	94	149	162	753	1242	1329	8.00	8.33	8.20
3 inches	93	115	148	952	1223	1593	10.23	10.63	10.76
4 inches	95	124	162	1052	1449	1804	11.06	11.68	11.13
5 inches	66	79	136	788	997	1647	11.55	12.76	12.18
6 inches	75	78	159	1042	1024	2036	13.87	13.13	12.80
7 inches	49	64	180	760	795	2534	15.50	14.96	14.07
8 inches	46	158	174	792	2634	2820	16.50	16.67	16.20
12 inches	45	149	43	1217	3629	1031	25.00	24.35	24.00
Total........	698	1225	1400	9072	17142	17116	141.01	142.71	138.66
Average......	69.8	122.5	140	907.2	1714.2	1711.6	14.10	14.27	13.87

TABLE III—NUMBER OF FLOWERS ON ELBERTA PEACH SHOOTS OF DIFFERENT LENGTH

	Number of observations			Number of flowers			Average flowers per shoot		
	Check	N.	P.N.K.	Check	O-N-O	P.N.K.	Check	O-N-O	P.N.K.
1 inch	99	127	87	153	203	126	1.54	1.59	1.47
2 inches	73	75	79	148	168	185	2.02	2.24	2.34
3 inches	102	126	131	295	397	374	2.89	3.15	2.85
4 inches	75	74	95	270	283	318	3.60	3.95	3.34
5 inches	70	78	81	298	363	339	3.40	4.65	4.19
6 inches	61	69	75	240	315	331	3.93	4.56	4.10
7 inches	52	43	50	221	217	209	4.25	5.04	4.60
8 inches	96	97	87	499	510	466	5.02	5.25	5.35
12 inches	95	167	60	577	978	403	6.07	5.85	6.70
16 inches	84	77	81	489	434	743	5.85	7.06	9.17
Total........	807	933	826	3190	3868	3494	38.57	43.34	44.11
Average.....	80.7	93.3	82.6	319	386.8	349.4	3.86	4.33	4.41
Per cent increase over check........								12	14
Odds........								194.8:1	15.4:1

on plots receiving different treatment, from the standpoint of hardiness and fruit production; and, in connection with harvesting data, color, maturity and firmness of fruit were studied.

It was evident from the first that nitrogen was a determining factor in both growth and production, but at no time could any beneficial effect be definitely traced to the use of either phosphorus or potassium. Increase in both tree growth and production resulted from the use of nitrogen either alone or in combination. This is shown in Table I, which is calculated from the growth of the trees through the entire period and yields of 1922 and 1923.

The records for 1924 are not included because of breakage of limbs from a heavy crop—the trees not being cut back any in pruning – rendered safe comparisons impossible.

Yields are closely correlated with tree growth for the preceding year. The average terminal growth of each plot for the years 1921–22 compared with the average yield for 1922–23 shows a correlation of +.8888, while the increase in trunk circumference for 1921–22 compared with the same yields shows a correlation of +.84444.

Yields are not only correlated with terminal growth of the previous season, but are largely determined by it. Table II shows that just as many fruit buds are formed on check terminals as on wood of equal length on trees in the nitrogen and complete fertilizer blocks.

The number of buds blooming is increased slightly by the use of fertilizers as shown by Table III, but this is largely a question of dormancy. The flowers on weak trees open 2 to 5 days earlier than on vigorous trees and the mortality among these early buds is greater.

The trees on all plots receiving nitrogen bloomed later than the checks and those not receiving nitrogen. The longer shoots on the check trees bloomed slightly later than the short ones, but they, also, showed the effect of early maturity.

Further evidence that fertilizers do not affect hardiness or resistance to frost is shown in Table IV. We had an excellent opportunity in 1923 to observe the effect of frost on trees under different treatment. Insofar as possible only buds in similar position and of the same stage of advancement were examined. The nitrate of soda and the sulfate of ammonia plots showed the least injury, but the buds examined were slightly less advanced than on the other plots.

TABLE IV.—DAMAGE FROM FROST TO TREES RECEIVING DIFFERENT FERTILIZER TREATMENTS

Block	Number branches counted	Total number buds	Number buds uninjured	Per cent uninjured
8-4-2	45	580	195	32.10
8-4-0	63	955	316	33.83
S. of A.	61	775	341	42.09
Check	42	485	170	35.13
8-4-4	80	678	241	36.95
N. of S.	94	414	232	56.72

There is considerable difference in the number of fruits set on similar wood from check and fertilized plots. The nitrogen plots in

TABLE V—NUMBER OF FRUITS ON ELBERTA PEACH SHOOTS OF DIFFERENT LENGTHS

	Number of observations			Number of fruit set			Average number fruit per shoot		
	Check	N.	P.N.K.	Check	N.	P N.K.	Check	N.	P.N.K.
1 inch	132	85	69	12	5	4	.076	.059	.058
2 inches	172	110	85	21	19	14	.122	.173	.165
3 inches	134	100	53	30	29	19	.224	.290	.302
4 inches	100	91	64	22	50	15	.220	.549	.234
5 inches	59	75	52	17	30	15	.288	.400	.288
6 inches	46	61	44	18	30	19	.391	.492	.432
7 inches	37	43	51	20	30	34	.541	.698	.667
8 inches	29	43	28	20	26	24	.690	.605	.857
12 inches	24	88	92	14	73	79	.583	.829	.859
16 inches	10	37	32	11	40	49	1.100	1.081	1.531
Total	743	733	571	185	332	272	4.235	5.176	5.393
Average	74.3	73.3	57.1	18.5	33.2	27.2	.424	.518	.539
Per cent increase								22	27
Odds								49.3:1	65.0:1

Table V show a gain of 22 per cent over the check and the complete fertilizer plots show a gain of 27 per cent. The principal gain is from the long shoots.

Table VI shows the percentage of buds blooming on all parts of 4 large limbs on each tree and the set of fruit on the same areas. All buds blooming were counted and the fruits were counted early in July. This compares buds on wood averaging about 3 inches long on checks and plots receiving no nitrogen to buds on wood averaging about 9 inches long on the plots receiving nitrogen. Here, nitrogen shows a small increase in the number of buds blooming and a very heavy increase supported by reliable odds in the amount of fruit set. The high percentage of set on all plots is due partly to a light crop of flowers after a heavy frost in 1923.

TABLE VI—THE EFFECT OF FERTILIZERS UPON (1) PERCENTAGE OF BUDS BLOOMING AND (2) PERCENTAGE OF FLOWERS SETTING FRUIT

	Combinations containing N.	Combinations containing no N	Average gain or loss	D	Odds
1	22.843±1.217	21.517±1.146	1.326	7.0998	2.41:1
2	44.915±1.967	10.028±1.406	−31.887	14.1260	4999:1
	Combinations containing K.	Combinations containing no K.			
1	23.3125±1.390	23.8950±1.465	.5825	7.5440	1.5:1
2	28.6775±4.162	22.9725±3.695	5.7050	11.038	8.35.1
	Combinations containing P.	Combinations containing no P			
1	24.7125±1.458	22.7638±1.308	−1.9488	7.3701	2.94.1
2	26.1875±3.232	25.3688±4.622	8188	13.804	1.5.1
	No fertilizers	Nitrogen only			
1	16.7075± .5561	22.54 ±3.005	5.8325	6.4221	8.3:1
2	4.5500±1.4920	49.18 ±1.113	44.6300	8.1442	830:1

In 1922, a third block was added to study the effect of time of application of nitrogenous fertilizers. All plots in this block received a uniform application of acid phosphate, but nitrogen was varied both in amount and in time of application. Applications were so timed that the first was made about a week before blooming, the second the middle of June or just before the heavy drop, and the third just after harvest, or usually in March, June and August.

The time of application of nitrogen to peach trees is of less importance than has been suspected. As already shown nitrogen applied just before blooming increases the set of fruit very materially, but a vigorous peach tree will set a large percentage of its buds without the use of nitrogen and, while nitrogen will increase the set, the fruit is usually smaller, so that the total yield will not be materially changed except in seasons when frost has reduced the number of buds. In Table VII the average of the plots receiving 2 pounds of nitrate of soda per tree in March is used as a check. The only plots which show a greater yield are the one receiving nitrogen in early June with no

TABLE VII—THE EFFECT OF VARYING TIME OF APPLICATION OF NITROGEN* ON THE PERFORMANCE OF PEACH TREES

	Check (average of 3)	Treatment Average	Average mean difference	Standard deviation	Student's Odds
1	2.8967±.3553	3.2567±.4932	.3600	1.4320	1.64:1
2	2.8967±.3553	2.5733±.5284	—.3233	.0583	124.2:1
3	2.8967±.3553	2.2933±.2119	—.6033	.4698	8.43:1
4	2.8967±.3553	2.4067±.3817	—.4900	.2337	19.6:1
5	2.8967±.3553	3.2400±.1889	.3433	.4359	4.26:1
6	2.8967±.3553	2.3467±.2112	—.5500	.2749	17.9:1

TERMINAL GROWTH IN INCHES

	Check average	Treatment Average	Average mean difference	0	* Odds
1	5.2057±.3670	4.4167±.2064	—.7900	.2439	43.34:1
2	5.2057±.3670	5.1733±.3669	– .0333	.4205	.098:1
3	5.2057±.3670	5.5000±.1609	.2933	.4622	3.3:1
4	5.2057±.3670	5.6267±.4161	.4200	.5515	3.06:1
5	5.2057±.3670	4.1600±.3255	1.0467	.6520	12.2:1
6	5.2057±.3670	4.4433±.2566	.7633	.3895	17.26:1

TRUNK CIRCUMFERENCE IN INCHES

1	1.3600±.2341	1.4333±.2487	.0733	.2149	1.93:1
2	1.3600±.2341	1.1400±.1818	—.2200	.2863	4.13:1
3	1.3600±.2341	1.3233±.2787	—.0367	.1573	1.58:1
4	1.3600±.2341	1.1867±.3037	—.1733	.1419	7.83:1
5	1.3600±.2341	1.3833±.2831	.0233	.1317	1.43:1
6	1.3600±.2341	1.1333±.1665	—.2267	.0736	40.0:1

*Two pounds of nitrate of soda per tree just before blooming used as check.

significant odds, and the one receiving nitrogen in both March and June, again with low odds. Plots 3 and 4 made a greater terminal growth, but much of this was fall wood and barren.

Those plots receiving all or a part of their allotment of nitrogen in August showed a reduction in yield with favorable odds. This is due in part to greater mortality of buds and in part to the fact that much of the terminal growth made in late fall is barren. Table VIII shows the relative amount of barren wood on plots receiving nitrogen at different seasons.

TABLE VIII—TABLE SHOWING RELATIVE AMOUNT OF BARREN WOOD AT TIP END OF CURRENT GROWTH FROM TREES UNDER DIFFERENT TREATMENTS

	PNK	N. Mar.	N M. & J	N M J & A	N A
Number of measurements....	140.00	164.00	157.00	143.00	121.00
Total in inches.....	2371.00	3010.00	2747.00	2660.00	2166.00
Average length.....	16.22	18.35	17.50	18.60	17.90
Inches barren......	308.25	409.50	423.00	465.50	472.00
Average length barren..........	2.20	2.49	2.69	3.25	3.90
Per cent barren.....	13.00	13.60	15.40	17.50	21.74

The season of growth and amount of growth seem to play an important part in fruit production. If growth is checked too early in

TABLE IX—THE EFFECT OF VARYING THE TIME OF APPLICATION OF NITROGEN ON THE SETTING OF ELBERTA PEACHES

Shoot length	Number of blossoms					Number of fruits set					Average number of fruits per shoot				
	March	March May	March May August	May	August	March	March May	March May August	May	August	March	March May	March May August	May	August
1	89	42	95	54	64	11	12	10	0	4	.1236	.2849	.1041	.0000	.0625
2	90	82	96	44	72	36	40	26	3	12	.4000	.4870	.2741	.0683	.1669
3	105	102	110	54	60	49	51	43	12	20	.4670	.5000	.3910	.2222	.3333
4	98	82	92	48	61	39	41	72	29	39	.3980	.5000	.7840	.6040	.6400
5	72	42	70	40	36	24	18	28	19	13	.3340	.4290	.4010	.4760	.3620
6	41	30	52	16	8	32	25	31	9	5	.8050	.8333	.5960	.5625	.6250
7	35	30	40	32	40	25	29	46	30	25	.7150	.9675	1.1500	.9390	.6250
8	46	28	34	18	28	41	24	29	17	20	.8910	.8550	.8525	.9450	.7150
12	52	68	70	46	57	55	92	77	65	69	1.0590	1.3510	1.1000	1.4110	1.2100
16	59	38	40	27	22	98	69	48	22	21	1.6600	1.8150	1.2000	.8150	.9550
20	24	25	31	27	37	52	69	46	45	29	2.8300	2.7600	1.4810	1.6700	.7850
30	23	28	32	32	48	45	80	87	52	32	1.9550	2.8470	2.7200	1.6500	.6670
Total	734	597	762	438	533	507	550	543	303	289	11.6376	13.63	11.0537	9.3630	7.1467
Average	61.17	49.75	63.50	36.50	44.42	42.25	45.83	45.25	27.55	24.08	.9698	1.1358	.9211	.8512	.6956

TABLE X—EFFECT OF FERTILIZER ON SIZE OF FRUIT

A	B	A	B	Gain or loss	0	Odds
Average check	S. of A.	5.6625±.0376	5.3950±.1119	—.2675	.24444	11.9:1
Average check	8-4-4	5.6625±.0376	5.6575±.1299	—.0050	.3351	1.3:1
Average check	8-4-2	5.6625±.0376	5.6725±.0862	.0100	.1938	1.3:1
Average check	8-4-0	5.6625±.0376	5.6575±.1325	—.0050	.3599	1.3:1
Average check	8-2-4	5.6625±.0376	5.7225±.1498	.0600	.3543	1.5:1
Average check	8-0-4	5.6625±.0376	5.6100±.1549	—.0525	.08186	4.7:1
Average check	4-4-4	5.6625±.0376	5.3875±.1050	—.2750	.2287	14.5:1
Average check	0-4-4	5.6625±.0376	5.3475±.0395	—.3150	.0836	275.5:1
Average check	N. of S.	5.6625±.0376	5.2175±.1350	—.4450	.3021	22.7:1

TABLE XI—EFFECT OF FERTILIZER ON COLOR OF FRUIT

A	B	A	B	Gain or loss	0	Student's Odds
Average check	S. of A.	4.5975±.0564	3.2750±.1266	—1.3225	.4460	138.5:1
Average check	8-4-4	4.5975±.0564	3.1425±.2394	—1.4550	.8568	31.5:1
Average check	8-4-2	4.5975±.0564	3.0225±.1425	—1.5750	.5395	132.9:1
Average check	8-4-0	4.5975±.0564	3.3050±.2423	—1.2925	.9483	19.0:1
Average check	8-2-4	4.5975±.0564	2.7875±.0776	—1.8100	.2615	1600:1
Average check	8-0-4	4.5975±.0564	4.5575±.2574	— .0400	.8204	1.3:1
Average check	4-4-4	4.5975±.0564	3.1775±.2453	—1.4200	.9387	24.4:1
Average check	0-4-4	4.5975±.0564	3.1775±.1706	—1.4200	.5832	80.4:1
Average check	N. of S.	4.5975±.0564	3.1975±.1733	—1.4000	.5964	72.9:1
Average check	8-0-0	4.6650±.1189	4.9300±.0048	.2650	.2550	3.1:1
Average check	0-0-4	4.6650±.1189	4.4950±.1741	— .1700	.6100	1.4:1

the fall the buds mature, pass through their rest period, and every warm day in winter and early spring advances them thus increasing the frost hazard in the spring.

On the other hand, late applications of nitrogen, or other factors which cause growth to continue too late into the fall, increases the mortality from winter injury to buds to a considerable extent and causes the production of a greater amount of barren wood.

From the standpoint of fruit set, a split application of nitrogen giving half the dosage before blooming and the other half in June proved slightly superior to making the application all at one time, in March. Three applications, March, June, and August, supplied too little nitrogen early in the season and caused late growth. The May application alone reduced the set considerably and a single August application caused a late fall growth which permitted considerable winter injury and caused a great deal of barren wood in addition to lowering the set of fruit.

Size, color and maturity are influenced largely by the same factors, --tree vigor, foliage, size of crop, and available moisture. Neither phosphorus nor potassium had any effect on size, color, or maturity. Nor did nitrogen, except as it affected the growth of the tree and the set of fruit.

Size increases as the number of fruits on the tree decreases.

Color was highest on the checks and those plots receiving no nitrogen, but no difference could be noted in favor of any element, but color decreases as terminal growth and foliage increase regardless of the cause of this increase. Color when compared with average terminal growth shows a negative correlation of —.7368.

Maturity of fruit was, in all cases, delayed a few days by the use of nitrogen but was not influenced by either phosphorus or potassium.

An attempt was made to study the effect of different fertilizer elements on the firmness of fruit by measuring the resistance to puncture at a given stage of ripeness. Equipment similar to that perfected by Dr. Murneek, for testing the ripeness of pears, as described in California Technical Bulletin No. 186, was used. No appreciable difference could be detected except on plots receiving a double dosage of nitrate of soda. Fruit from these plots was softer than from any others by several pounds in pressure required to puncture.

From the foregoing observations and data we must conclude that the factors concerned in peach production, aside from frost hazard and drought, can be grouped under one single head, growth. Any factor which encourages tree vigor, whether it be fertilizers, pruning or water supply, increases production up to the point where the growth is too vigorous to permit the setting of fruit buds, or is prolonged so late into the fall that the wood is barren and the buds not sufficiently matured to avoid winter injury.

Peach Pruning Studies

By F. P. CULLINAN, *Experiment Station, Lafayette, Ind.*

IN THE spring of 1921 the Horticultural Department of the Purdue Agricultural Experiment Station began a study of some peach pruning problems, at the request of growers in Knox County, Indiana. The pruning and training of young trees, as well as of older bearing trees, offers quite a different problem in a section where only 3 crops out of 5 or possibly 2 out of 5 may be expected from that of a section where peach crops can be expected more frequently. The use of nitrogen fertilizers in peach orchards as a means of increasing growth and fruitfulness, has become quite a general practice and the response resulting from nitrogen applications, accompanying varying amounts of pruning, is quite noticeable both in young and bearing trees. Furthermore, cultural methods used by growers in trying to combat the disease, bacterial spot or bacterium pruni, with the present limited knowledge as to its control, are factors affecting growth and consequently the pruning required.

The studies reported in this paper were conducted in orchards near Vincennes, Indiana, on a sandy loam soil. Young peach trees on this soil usually make a very good growth, without the use of nitrogen fertilizers. Two and 3 year old trees, especially if cut back, will make terminal shoot growths 3 to 5 feet in length. Bearing trees, show a response to the use of nitrogen fertilizers.

The trees used in these studies consisted of a blook of 50 Elberta 5 years of age, which had received light pruning up to the time this work was started, and a block of 32 eight-year old trees, consisting of 24 Elberta. The younger block had borne only a few fruits on each tree, prior to the time of the experiments. The older block had borne a fairly heavy crop in 1920, but previous to that year spring frosts and winter freezes had killed the buds.

PRUNING TREATMENTS

The pruning treatments given these trees were as follows: (1) Cutting back and thinning out. In this treatment, the terminal shoots at the end of the main scaffold branches were cut back one-third to one-half. Where the upright shoots produced on a branch were growing close together, they were thinned; (2) Light cutting back of terminal shoots to lateral shoots, growing outward from the center of the tree. In the longer, more vigorous shoots, this portion removed would average about 1 foot in length. On the shorter terminals with heavy laterals, no pruning was done. Vigorous shoots with few laterals developed were removed entirely if crowding others, or were left with no heading back. New growths arising from these were shortened back the following year; (3) Heavier heading and thinning than that described under (1). The terminal shoot was headed back one-half. The centers of all trees were kept open and an open head maintained. All of the pruning was given in the dormant

season. The results secured with the younger trees will be given first.

In 3 of the 5 years, 1921, 1924, and 1925, the crop was reduced by freezes. In 1921, it was a frost at blossoming time, in 1924, low winter temperatures caused a failure, and a December freeze in 1924 killed all but about 2 per cent of the buds of the 1925 crop.

Response in Growth

The response of the five-year old trees, following the manner in which they were pruned the first year, was quite definite. In 1921 the trees had received an application of nitrate in anticipation of a crop. However, it was an unusually early spring and a temperature of 26 degrees, when the trees were in bloom, killed all the blossoms. The trees made a strong growth during the season. The trees that had received the heavier cutting back made the greatest length growth per shoot. Terminal shoots on the heavier headed trees averaged over 36 inches in length. These bore slender laterals over 1 foot in length which contained few fruit buds. There were also few fruit buds on the main shoots of this type of growth. The tall shoots, 4 to 5 feet in length, which were produced at the ends of the upright scaffold branches, were often close together and shaded the new shoots that developed on branches below them. The shoots in the interior of the tree were long and spindling, yellowish green in color and in general devoid of fruit buds. If fruit buds were borne there was only 1 at a node.

The trees receiving lighter pruning and of a different nature, that is, thinning and renewal to laterals on the main shoot, produced new shoots about 30 inches or less in length with numerous well developed stocky laterals. Both the main shoot and laterals bore fruit buds developed well down to the base. The centers of the trees as well as the framework of scaffold branches were more open to sunlight throughout the season.

In 1922 and 1923 which were crop years, the growth was similar to that produced the first year of the experiment, 2 pounds of nitrate of soda were applied to each tree before blossoming. However, the average length growth per shoot was reduced on the more lightly pruned trees. On these trees the terminals arising from the more upright scaffolds were about 28 inches in length with numerous laterals. The growth of terminals on the more horizontal limbs was slightly less. The trees were open to sunlight and there were numerous short spur-like growths 3 to 4 inches in length developed on 2 and 3 year wood. These were well filled with fruit buds. The crop on these trees apparently checked the terminal growth.

The headed back trees responded in growth similar to the previous year. The upright branches produced many shoots. These were over 3 feet in length with fewer laterals and fruit buds. While terminal growth was reduced some by the fruit produced, it was not so noticeable as with the more lightly pruned trees. The centers of these trees were shaded and the new growth was spindly, in the shaded area.

In 1924 a winter freeze killed all the fruit buds and the pruning was heavier on all plots. All cut-back plots were headed back more severely and thinned out. The renewal-thinned trees had the terminals shortened back to strong laterals and some upright branches and shoots were removed entirely. While this pruning was rather heavy in amount of wood removed, it differed from that given to the other plots in that it was more of a thinning and less of a general heading back. No fertilizer was applied and little cultivation was given. Despite this fact, the headed back trees made terminal growths similar to those produced in 1922 and 1923, and the shading caused by the dense growth of shoots was also apparent. The trees renewed by thinning were very open. There was an excellent distribution of new shoots 12–16 inches in length over the main scaffold limbs from the crotch out to the terminal branches. There were also many short spur growths 2 to 6 inches in length. These shoots completed their growth early in the season and were filled with well developed fruit buds at each node from the base to the tip.

In 1925 there was also a crop failure due to injury by low winter temperatures The trees were given a pruning similar to that in 1924. No fertilizer was applied and little cultivation was given. These trees were now 9 years old. The more lightly pruned trees which had had no heavy renewal, were slowing up in growth, yet they were producing an abundance of fruit buds. It would have been of interest to compare growth on these trees with more severely pruned trees if fruit had been borne during the years 1924 and 1925, and if nitrogen and cultivation had been given during this time. However, at 9 years of age these trees which had produced only 2 light crops of fruit under the condition of these studies, were not in need of a heavy renewal pruning. They were of better form, more spreading and had a greater bearing surface than trees which had received annual heading back during this period, and with much heavier heading back in years of a crop failure. While all trees were pruned to an open head, the heavier-headed trees of this age had a tendency to fill in the center during the growing season. Also, the headed-back trees were quite upright in form, the scaffold branches had not yet been spread by heavy crops.

Fruit Production

The yield records for the years when a crop was produced are given in Table I. In 1921 the crop was killed by a freeze. In 1922 the six-year old trees were all well filled with buds and there was a heavy set of fruit. This may be considered the first heavy crop. The fruit was thinned on all plots. It will be observed that the trees receiving the lighter pruning produced the heaviest yield. There was not a great difference in the size of fruits produced except on plot 5, which received the lightest pruning and produced the heaviest yield. The fruits from this plot were of a good commercial size, but smaller than those produced on the other plots. This undoubtedly is due to the greater number of fruits per tree borne on this plot. Student's

method for determining the significance of the differences in yield of the plots as affected by the various pruning treatments, was employed. By this index it will be observed that the results the first year are only suggestive. In only one case, where the yield on plot 5 is compared with plot 3, are the odds greater than 30 to 1. However, they suggest a heavier yield on the trees receiving lighter pruning.

In the following year, 1923, there is a noticeable difference in the yield. Plot 2 shows a mean gain of 42 pounds per tree over plot 1, and about 52 pounds per tree over plot 3. Plot 4 another row receiving light heading, shows a mean gain of 65 pounds per tree over plot 1, and 66 pounds per tree over plot 3. These differences give odds that are significant. On seven-year old trees that have had a general heading back, the yield has been greatly reduced. It will also be noted that the yield on Plot 5 which had very little pruning, was much less in 1923 than that of moderately pruned trees, but in the years 1923 and 1924 it produced more fruit at this age than trees more heavily pruned.

The smaller size of the fruit on plots 1 and 3, considering the relative yields with other plots, may be attributed to the fact that these fruits were less mature at harvest time. They were produced under very shaded conditions, were of poor color, and were about 1 week later in ripening. The fruit was of much poorer quality than that produced on the more open trees

Results With Older Bearing Trees

At the time the experiments were started with five-year old trees a number of seven-year old Elberta were given similar pruning treatments. These trees had produced only one crop of fruit up to this time.

The trees in this experiment receiving a more general heading back produced a type of growth similar to that already described for trees of 7 years of age. The same was also true for the trees kept open by thinning and light cutting back of terminals to laterals. However, after the production of 2 heavy crops of fruit in 1922 and 1923, the amount of rank shoot growth was not so noticeable on the heavy headed trees. The trees were spread by the heavy crops of fruit and terminal growth was much less. Trees receiving renewal by thinning to laterals and the renewal of shoots, were very spreading at 10 years of age, the bearing surface was much greater, and the new growth on the main limbs consisted of short spurlike growths, 2 to 4 inches in length. Longer shoots were also produced from the main limbs well down into the head of the tree.

In 1924 when the crop was killed by a freeze, all trees were renewed by heading back and thinning. No fertilizer was applied but, the trees received 2 spring cultivations. The heading back under these conditions did not produce the heavy shoot growth produced by such renewal on trees of 7 or 8 years of age where the latter had produced only a few light crops of fruit. However, the trees trained by thinning and renewal to laterals were more open and possessed an

TABLE I

Number: Plot	Number: Trees	Treatment	*Average yield in pounds per tree: 1922	Average number per bushel	1923	Average number per bushel	1925	Average number per bushel
1	9	Cutting back one-fourth to one-third to first whorl of laterals	222.7	182	62.6	100	29.9	100
2	9	Cutting back terminals of strong upright shoots to laterals. Thinning of competing shoots	245.0	182	129.2	105	33.5	92
3	10	Cutting back one-half of terminal growth and thinning	203.5	172	71.5	140	24.0	82
4	9	Light heading only to laterals and thinning	230.4	192	139.9	110	19.7	82
5	10	No heading, light thinning only to open the center	282.5	230	95.5	105	12.0	96

MEAN GAIN

	1922	1923
Plot 2 over 1	32.4 pounds, odds 7 to 1	42.0 pounds, odds 40 to 1
Plot 2 over 3	37.1 pounds, odds 13 to 1	51.9 pounds, odds 151 to 1
Plot 4 over 3	22.2 pounds, odds 13 to 1	66.0 pounds, odds 96 to 1
Plot 5 over 3	79.1 pounds, odds 37 to 1	24.2 pounds, odds 8 to 1
Plot 4 over 1		65.0 pounds, odds 136 to 1

*Complete loss of crop from low temperatures in 1921 and 1924. 1925 crop reduced by freeze.

TABLE II—YIELD OF ELBERTA TREES DURING THE EIGHTH TO TWELFTH SEASONS

Plot	Number of trees	Treatment	Average yield in pounds per tree*: 1921	1922	Average number per bushel	1923	Average number per bushel	1925
1	6	Heading back all main terminals one-third. Thinning	75	375	220	279	120	101
2	6	Heading upright shoots to strong laterals. Thinning	114	448	212	307	100	50
3	6	Heading back all main terminals one-half. Thinning	76	419	207	300	120	75

*Spring frosts reduced crop in 1921: low winter temperatures caused failure in 1924 and reduced crop in 1925.

excellent scaffold of secondary branches, to which the limbs could be cut back without leaving stubs. Trees can be renewed in this manner without losing a crop the year following.

Yield of Fruit

The production of fruit on Elberta trees during the eighth to twelfth season is given in Table II.

This is not a large number of trees on which to base conclusions, but in the light of the data already presented they are quite suggestive. It will be observed that in the years of a heavy crop there is not a marked difference in yield between the plots. However, the lightly headed trees produced more fruit in the first year of 1921 and the crop year of 1922. This heavy fruiting did not result in a reduced crop in 1923. The fruit was of good marketable size. These trees had all received nitrate of soda and good cultivation in those years. The heavier crop in 1921 is undoubtedly due to the larger bearing surface and where a larger number of buds surviving the frost were left on the tree. In contrast to this it appears that in 1925 when low winter temperatures killed most of the fruit buds a greater proportion came through uninjured on the more heavily pruned trees. These fruits were borne principally on short, slender growths that were produced from nodes on strong growing branches 2 or 3 years of age. These short slender growths had green colored bark on the underside and evidently were produced later in the season than short spurs growing on the more open branches or well matured laterals. All buds were killed on the latter types of growth on both heavily pruned and lightly pruned trees. It may be that the buds on these late growing shoots differentiated later and the flower parts were thus in a less advanced stage at the time of the December freeze. Growth ceased early in 1924 followed by a dry autumn. There was considerable warm weather and sunshine during October and November. It was quite noticeable in other orchards that buds produced on similar growth on heavily headed back trees survived a temperature of —14 degrees F. in late December.

Discussion

On a particular type of soil or in a locality where young peach trees grow very vigorously, it appears that the open head type of tree may be secured with less difficulty by a minimum of heading back during the first 5 years. A general heading back of strong growing terminal shoots which is often given to keep young peach trees from becoming too upright in growth habit, usually results in a dense shoot growth which shades the interior of the tree and requires considerable thinning to remove this type of growth. Frequently 5 to 6 foot shoots or "pole growths" as the grower calls them, result from this type of pruning. The removal of these may constitute a very heavy pruning on young trees. A heading back which is a combined process of renewal of upright shoots to strong outside laterals, and thinning by removing shoots entirely where too numerous, will give a

more open and spreading tree at 5 or 6 years of age. The tree will also have a greater bearing surface and will bear larger crops of fruit from the fourth to the seventh year at least. This is of importance in sections where the frost hazard is a limiting factor in peach growing.

The time for profitable renewal of peach trees will depend upon the vigor of the tree and the amount of fruit borne. In these experiments where trees had not borne heavy crops until the seventh or eighth year on account of frosts and winter freezes, light pruning of a thinning-renewal nature gave heavier yields in years of a crop. The practice of doing lighter pruning in the year of a frost and relatively heavier pruning in the year of a crop would appear to be a wise practice. Trees making 2 to 3 feet of terminal growth in years of a crop are usually not in need of a general renewal in the non-crop year. Trees making considerably less growth than this and which have been weakened by heavy crops or other causes, will respond to renewal pruning with a very desirable type of shoot growth.

The peach is very profoundly affected by soil and climatic conditions and it is realized that in some sections heavier heading of peach trees, even when young, would not produce the heavy shoot growth as obtained in these experiments, though it probably would decrease the bearing surface and yield of young trees.

A Study of Flower Bud Formation in the Dunlap Strawberry

By J. U. Ruef and H. W. Richey, *Iowa State College, Ames, Iowa.*

IN MAKING a general study of the growth and fruiting habit of the strawberry and especially of the plant's responses to the application of various fertilizers, it was deemed advisable to first make some rather detailed studies of the plant. We attempted to determine the *time of flower-bud formation and the effect of the use of various fertilizers on fruit bud differentiation and on the fruitfulness of the plants.

All previous work dealing with fruit bud differentiation has been freely drawn upon for suggestions and assistance in making this study. In only a few cases were we able to find work on the time of flower bud differentiation in the strawberry. Goff (3) fixed the date of flower bud differentiation for the strawberry in Minnesota as

*Time of flower bud formation in this paper is taken to mean the time when microscopically visible differentiation has taken place.

Note: This paper is a preliminary report of but one year's study of a portion of a rather extensive and intensive study of the growth of the strawberry plant. The study was formulated and is under the direction of H. W. Richey. The data for this paper, however, were taken chiefly from the work done by J. U. Ruef and to a less extent from that done by S. H. Tung. Both of these men were graduate students at the Iowa State College, 1924.

September 20, and expressed as his opinion that the differentiation took place at the same time in the mother plant and in the various runner plants. Marrow (4) determined the time of flower bud formation in Iowa as September 18. He likewise stated that the age of the plant had no influence on the time of fruit bud formation. Chandler (1) in a fertilizer study with the strawberry in Missouri, considered February and March as the time of differentiation, whereas Gardner (2) in a later study in the same state, gives October 30 as the date of fruit bud differentiation. Different investigators reported different times of fruit bud formation even for similar localities. Judging from the results reported in recent years relative to fruit bud differentiation in other fruits, it appeared to the writers that the time of flower bud formation in the strawberry would vary with the environmental factors such as climate and soil, and would vary with the age of the individual plant, since such factors certainly influence the internal nutritional condition of the plant. Likewise the various varieties probably have different conditions at which flower bud formation takes place. If the carbohydrate-nitrogen ratio is one of the prime internal nutritional factors that influences the time of fruit bud formation, it is conceivable that this ratio might vary with the season, with the different periods of the season, with different varieties of the same fruit, and even with different aged plants of the same variety.

With these points in mind we attempted to determine the time of fruit bud differentiation and its early development in the Dunlap strawberry at Ames, Iowa, during the fall and winter of 1924-25. These investigations, therefore, comprised a study of the formation of the individual strawberry fruit stalks and flower buds of the different aged plants on the same runner. A similar study of the time of flower bud differentiation and fruit stalk development was made of plants growing in sand cultures to which various fertilizers were added.

Bud Differentiation in Field Grown Plants

The plants used for this study were the different aged runner plants from Dunlap plants set at Ames, Iowa, in early April, 1924. The plants were growing on a rich prairie soil, but due to rather dry weather during the early part of the season, runners did not set until early July, after which a fair to good growth was made. In this preliminary work no definite date of the formation of the various plants on a runner was noted. The runner plants were forming at approximately the same rate on the various mother plants so that in selecting plants of a similar size and the same position on the runners of the same or different mother plants, it was assumed that the plants selected for study were near the same age. This supposition was further supported by the fact that the runners selected had practically the same number of plants on them.

Plants were taken for histological study at 5 irregular intervals from September 7 to December 13. Earlier in the season plants were marked in such a fashion that their origin could be determined at

the time of removal from the field. The plants were grouped in series according to their position on the runner. All number one plants on runners constituted one series, all number two plants on the same group of runners constituted the second series, etc., up to and including the fifth plants on the runners which constituted the fifth series. The crowns of the plants were taken and after being carefully trimmed were placed in Gilson's killing solution. The buds were then dehydrated and embedded in paraffin by the method usually employed in histological study. These buds proved to be very brittle and it was impossible to get good serial sections on a rotary microtome. They were, therefore, sectioned on the slide microtome with a thickness of 15 to 20 microns. The sections were placed in xylo to remove the paraffin, placed on slides and immersed in clove oil containing safranine. After 15 minutes they were taken out and mounted in Canada balsam. Mr. Finch, who is continuing the study this year, has improved the method so that suitable serial sections can be obtained.

Bud Differentiation in Sand Culture Plants

Plants for this purpose were similar to the ones used for the above study. In early October the fourth and fifth plants on the runners were taken just as they were forming roots. Very uniform plants were selected. These plants were potted in 2½ inch clay pots using good loam soil commonly used in our greenhouse benches. After a fairly good root system had developed, the soil was washed from the plants, a rigid selection for uniformity was made, and the chosen plants set in glazed pots containing 11 pounds of washed river sand. Different fertilizers, singly and in combination, in varying amounts and at different times, were applied to the plants. A basic fertilizer treatment made of nitrate of soda, acid phosphate and muriate of potash equivalent to a 4–8–2 mixture at the rate of 500 pounds per-acre, was applied to all plants. After receiving the proper fertilizer applications the plants were placed in a cold frame and protected from severe climatic conditions until January 7 when they were brought into a greenhouse and placed under suitable forcing condition.

Plants were taken for histological study at 3 different periods. The first collection was made at the time the plants were placed in sand and the various fertilizers applied. From this material it was proved that flower bud differentiation had not taken place in the plants used for the fertilizer experiment. A second collection was made when the period of forcing began and a third collection 9 days later. These buds were killed, treated with hydrofluoric acid for 4 weeks, dehydrated with alcohol, which was displaced with cedar oil, and then infiltrated with paraffin. This process gave much more satisfactory sections than the previous one in which hydrofluoric acid was not used.

THE TIME AND ORDER OF FRUIT BUD DIFFERENTIATION ON THE SAME FRUIT STALK AND IN THE DIFFERENT PLANTS ON A RUNNER

It is impossible to determine definitely the exact time of fruit bud differentiation in the strawberry or any other fruit solely by the aid of the microscope. The initiation of the differentiation of the flower bud is undoubtedly the result of a chemical condition rather than a pronouncedly visible morphological change. We will consider, however, that the time of differentiation is indicated by the initial morphological changes in the bud that can be detected by the aid of the microscope.

Judging solely from our knowledge of fruit bud formation in horticultural plants as a whole one would expect the time of differentiation in the strawberry to vary according to the climatic and soil conditions in the section of the country in which the plants were grown, to vary with the particular season in that locality, and to vary with the specific variety studied. In this study it was found that the Dunlap strawberry plant growing at Ames, Iowa, on a fertile soil during a fairly dry season up to late July, differentiated its primary flower buds on the first plants of the runner during the first week of September. The first buds collected on September 7, 1924, showed that differentiation had taken place a very short time previous to the collecting of the buds. It was found that the period of differentiation was not confined to a short time centering around any specific date, but on the contrary flower bud differentiation was observed to be taking place continuously from the beginning of September to the middle of December after which no further collections were taken from the field grown plants. It is conceivable that differentiation might continue uninterrupted until blossoming time in those localities where climatic conditions permitted.

There is a gradual development of the strawberry fruit bud from the time of differentiation to the development of the pistils Valleau (5) has classified the flowers on the fruit stalk into primary, secondary, tertiary, etc., according to their position on the fruiting stem and their order of blooming. We found that there was a difference in the degree of development or maturity in the individual flowers upon a fruit stalk at a given time. The degree of development of the flower parts varied according to the position of the respective flower buds on the fruit stalk. The primordial sepals of the primary flower had formed when the first indications of the differentiation of the secondary blossom were evident. When the tertiary fruit buds were first visible, the secondary flowers possessed primordial sepals and the primary flower was complete with the exception of the fully developed pistils. We do not, at this time, have satisfactory evidence on the development of the individual flower stalks of the same plant.

Just as there was found to be a difference in the degree of development in the flowers of an individual fruit stalk at a specific time, so also there was found to be a difference in the degree of development in the different fruit stalks of the various plants on a runner. A series of 5 plants on a runner showed a gradual development of

CHART I—THE PROGRESSIVE DEVELOPMENT OF THE STRAWBERRY FLOWER BUDS AND FRUIT STALKS

Date of collection	First plant	Second plant	Third plant	Fourth plant	Fifth plant
September 7, 1924	Differentiation of fruit stalk				
September 15, 1924	Differentiation of primary flower	Differentiation of fruit stalk			
October 10, 1924	Primordial sepals Primary flower sepals petals anthers primordial pistils Secondary flowers primordial sepals primordial petals primordial anthers Tertiary flowers differentiation	Primary flower sepals petals Secondary flowers sepals primordial petals	Primary flower sepals (primordial) Secondary flowers differentiated		
November 17, 1924	Primary flower sepals petals anthers (lobed) pistils Secondary flowers sepals petals anthers primordial pistils Tertiary flowers sepals petals primordial anthers Quarternary flowers differentiation	Primary flower sepals petals anthers pistils Secondary flowers sepals petals anthers primordial pistils Tertiary flowers differentiation primordial sepals	Primary flower sepals petals anthers primordial pistils Secondary flowers sepals petals primordial anthers Tertiary flowers differentiation	Primary flower sepals petals anthers Secondary flowers primordial sepals	

December 13, 1924	Primary flower sepals petals anthers (lobed and pistils filaments) (clefted) Secondary flowers sepals petals anthers (lobed) pistils Tertiary flowers sepals petals anthers primordial pistils Quarternary flowers sepals petals primordial anthers	Primary flower sepals petals anthers (lobed) pistils Secondary flowers sepals petals anthers primordial pistils Tertiary flowers sepals petals primordial anthers Quarternary flowers sepals primordial petals	Primary flower sepals petals anthers primordial pistils Secondary flowers sepals petals anthers primordial pistils Tertiary flowers sepals primordial petals Quarternary flowers differentiation	Primary flower sepals petals anthers primordial pistils Secondary flowers sepals petals primordial anthers Tertiary flowers differentiation	Primary flower sepals primordial petal Secondary flower differentiation

the fruit stalks of each plant, but the degree of development in each stalk at any given time varied with the distance of the runner plant from the mother plant. In the same fashion that the primary flower in a fruit stalk differentiated before the secondary flowers, so the flower stalks and flower buds on the first runner plant formed before they did on the second runner, and on the second previous to their formation on the third, etc. The older plants on the runner showed differentiation first.

A specific example will serve to illustrate this point more fully. On October 10, the fruit stalk on the first plant on a runner had reached the stage of development in which the primordial pistils were visible in the primary flower, the anthers showed in the secondary flowers, and the tertiary flowers could just be detected. In the second plant on the runner the petals and anthers were visable in the primary flower and the sepals and primordial petals were noticeable in the secondary flowers. In the third plant only the primordial sepals could be seen in the primary flower, but no differentiation of the secondary flowers was visible. Thus we found a progressive differentiation of flower buds on the same fruit stalk and a progressive development of fruit stalks and flowers on the runner plants, the amount of development becoming less as the distance from the mother plant became greater.

It will be noted from a study of the accompanying chart that differentiation of the flower buds on the first plant to form occurred about a week earlier than the differentiation of the buds on the second plant. As time advanced a greater interval elapsed before the differentiation of the primary flower on the next plant of the runner. This suggests that the differentiation and development of the strawberry flower bud is influenced by an internal nutritive condition that is attained earliest in the older plants of a runner which are formed at a time of the year more favorable for plant metabolism. Those plants which first reach the stage in their development where the utilization of products for further growth is less than the production of such products, will have an accumulation of such products and, therefore, will be the first to differentiate flower buds.

The chart shows further that the first visible indication of differentiation was noticed in the first plant of the runner on September 7; it shows the gradual development of the different flowers on the same fruit stalk; and the progressive development which occurs in the various plants of the same runner.

Winter Injury of Different Plants on the Runner

The variation in the time of differentiation and the differences in the degree of development of the plants and flower buds proved to be rather interesting from the stand point of winter injury. Shortly after applying a straw mulch most of it was blown off certain parts of the planting. We had at Ames, a fairly cold winter, but no covering of snow on the strawberry plants. During the winter we did not experience alternate periods of freezing and thawing which causes

the plants to "heave" so the plants were not destroyed in this fashion. The number of plants used for the study was small, but the figures given in the table are at least suggestive. The first plants on the runners—those in which differentiation had occurred in the early fall and in which the fruit stalks had more fully developed by December, survived the winter best. The table indicates that the earlier the date of fruit bud differentiation and the more fully developed the flower stalk the greater is the plant's resistance to winter injury.

WINTER INJURY

Position of plant on runner	Number of plants winter killed	Percentage winter killed
First	0	0
Second	2	4
Third	15	30
Fourth	45	90
Fifth	48	96

THE EFFECT OF FERTILIZERS ON THE TIME OF FRUIT BUD DIFFERENTIATION AND DEVELOPMENT AND ON THE NUMBER OF FRUIT STALKS PRODUCED

In this paper we will limit ourselves to a brief statement of the effect of the various fertilizers on the time of flower bud formation, the degree of development, and the relative number of fruit stalks formed by the plants under the different fertilizers treatments. For this study the plants set in washed sand and treated with various fertilizers and grown in the greenhouse were used. As stated previously, buds were collected for histological study on January 10 and 19. Upon examination these plants showed a wide variation in the time of fruit bud differentiation and the degree of development. The results of the application of fertilizers on the time of differentiation can be summarized briefly as follows:

Acid phosphate, either singly or in combination, hastened fruit bud differentiation and development.

Nitrogenous fertilizers in general retarded development although at first heavy applications of nitrate seemed to stimulate differentiation.

Muriate of potash retarded differentiation.

In regard to the number of fruit stalks formed under the various fertilizer treatments the plots arranged themselves in the same order.

The results indicate that the fertilizers had some influence on the time of differentiation and the rate of development of the flower buds, and also some influence on the number of fruit stalks formed.

SUMMARY

The initial differentiation of the fruit bud of the Dunlap strawberry on the first runner plant took place in early September at Ames, Iowa, in 1924. The development of the fruit bud was a gradual mor-

phological change which continued, from its time of differentiation until the middle of December after which time no further collections were taken from the field. The time of differentiation of the various buds on a fruit stalk depends on their relative position on the stalk, the development being progressive from the primary to the secondary, tertiary, etc. The time of bud differentiation in the individual plants of a runner differs according to the relative position in age and the time of formation of the plants in relation to the mother plant and to one another. This would suggest internal nutritive relationship. Those plants in which differentiation and development were fartherest advanced were more resistant to winter killing.

The use of various fertilizers singly and in combination, in sand culture plants forced in the greenhouse, appeared to have some influence on the time of formation and rate of development of flower buds and on the number of flower stalks formed.

Conclusions

Since flower bud formation in the strawberry takes place over a protracted period of time; and since the time and degree of differentiation appear to be associated with the age of the plant; and since flower bud differentiation is generally accepted to be due, in large part, to an accumulation of plant food; and since those plants in which the flower buds were most developed and consequently probably more mature, were able to better withstand severe winter conditions, it is conceivable that production of satisfactory berries can be improved by cultural, fertilizer and other practices properly applied.

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Use of Plant Characters in Identification of Red Raspberry Varieties†

By J. D. WINTER, *University Farm, St. Paul, Minn.*

FOR SOME time there has been need for a practical method by which raspberry varieties may be identified with certainty at any time during the growing season without reference to the fruit. With this purpose in mind a study was made of varietal characters of the red raspberry as found throughout the state of Minnesota under widely different growing conditions. This study was commenced in the spring of 1925 and continued intensively during the entire growing season. Many plantings in many parts of the state were studied. The character of the fruit was not taken into consideration except as a means of checking up on identification.

It was soon determined that certain plant characters are relatively constant for a given variety under varying conditions of growth. Such characters are of primary importance in the identification of varieties. Certain other characters of additional value are relatively constant for a given variety under similar conditions of growth and exposure to sunlight, but may vary to a considerable extent under different growing conditions. This is true of such characters as the distribution and intensity of color on the spine and on the leaves at the growing tip of the cane. There are also characters such as the form or shape of the leaf, which are relatively distinct, but which may vary to such an extent within a given variety that they are of only minor importance in identification.

Varietal characters of primary importance for identification purposes were found to be the abundance, color and structure of the spines* on the cane and on the petiole of the leaf; the number of leaflets to each petiole; the relative intensity or value of color of the foliage; the relative height of the cane and whether the cane is conspicuously glaucous or otherwise.

The abundance of spines on the cane may vary from none to many. Varieties may be classified into 2 divisions, those with no spines or very few, and those with spines common to very numerous. For this purpose canes not less than half grown are taken, as very young canes do not exhibit distinct varietal characters. These spines may be sharp and rigid, or they may be comparatively flexible or bristle like. The base of the spine may be enlarged into a distinct nipple-like structure which may be readily observed by means of a hand lens. In some varieties the spine may enlarge toward the base sometimes becoming almost triangular and in other varieties there may be no pronounced enlargement of any kind. The distribution and intensity of color on the spine are characteristic, but may vary a great deal through differences in season, exposure to sunlight and other

*The term "spine" is used to denote the botanical term "prickle"

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conditions. The color of the enlarged portion or base of the spine when present, may vary from green to different tints or shades of red and is often very helpful in identification.

The spines on the petiole of the leaf may differ from those on the cane, particularly in abundance and structure. For example, plants of the varieties King and Latham which are quite similar in many respects (including spines on the cane) may be separated with absolute certainty by comparison of the spines on the petiole. The spines on the petiole of the leaf of the King variety are very numerous and hair-like while those of the Latham are much less numerous and retain their spine-like character.

The prevailing number of leaflets on each petiole in some varieties is 3 and in other varieties 5 is the most common number. In some varieties 3 leaflets occur about as often as 5. The prevailing number of leaflets for 1 variety may be 3, but 5 may occur quite often. In another variety with 3 leaflets prevailing the occurrence of 5 leaflets may be very rare. These are valuable characters for identification.

The foliage of some varieties has a characteristic light or dark green color. Other factors such as the fertility of the soil and disease may modify this, so that the relative color rather than the actual color must be considered.

Some varieties normally have a very tall vigorous growth and other varieties are normally of dwarf growth. This condition also may be modified by soil fertility, disease and other factors so that relative growth rather than actual growth must be taken into account.

The canes of some varieties are conspicuously glaucous, in other varieties the canes are only moderately glaucous and in some varieties this glaucous condition is apparently absent or practically so. The amount of this glaucous bloom appears relatively constant for a given variety and is at times of considerable assistance in identification.

These studies were based on a total of 15 varieties of red raspberries which came under observation. A preliminary key to these 15 varieties has been prepared from the data obtained and is given below.

Key to Certain Varieties of Red Raspberries

A—*Spines on cane absent or very few.

B—Spines on cane usually absent.

C—Leaflets mostly 5.

Leaves large, very dark green, apex acute, serratures medium to deep; occasional small green spines on petiole; canes strongly glaucous. . June

BB—Spines on cane very few.

C—Leaflets mostly 3.

D—Canes moderately glaucous.

Leaves broad in relation to length, apex acute, serratures shallow to medium; spines extremely few on mature canes, short, red, with small but distinct green base; spines on petiole few to common; canes short to medium. . . . . Loudon

DD—Canes not obviously glaucous.

Leaves very dark green, apex acute, serratures deep to very deep;

*The term "spine" is used to denote the botanical term "prickle."

Note—For purposes of identification the canes not less than half grown are considered, as very young canes do not exhibit distinct varietal characters.

spines on cane short, red with distinct red base; very few spines on petiole; canes tall . . . . Marlboro

CC—Leaflets mostly 5.

D—Canes moderately glaucous.

Leaves small to medium, somewhat narrow in relation to length, apex acuminate, serratures medium deep; spines on cane short to medium, slightly red, with no distinct base; many spines on petiole; leaflets rarely 3 . . . . **Miller

DD—Canes not obviously glaucous.

Leaves with characteristic drooping habit, apex acute, serratures shallow to medium; spines on cane short to medium, red, with no distinct base; petiole with few spines, canes short. . . . Eaton Crimson Beauty, Idaho, Iowa, Paragon

AA—Spines on cane common to very numerous.

B—Spines on cane rigid, sharp and distinctly swollen toward the base, sometimes becoming almost triangular.

C—Leaflets mostly 3.

Leaves moderately broad, apex acute, serratures medium to deep; spines on cane extremely numerous, medium to long, slightly red, with prominent green base; numerous spines on petiole; canes moderately glaucous; leaflets rarely 5 . . . . Herbert

CC—Leaflets as frequently 5 as 3.

D—Tip of new growth yellowish green.

Leaves somewhat narrow, apex acuminate, serratures medium to deep; spines on cane short to medium, green, with frequent red tip and prominent green base; petiole with many spines; canes very tall, moderately glaucous . . . . Golden Queen

DD—Tip of new growth slightly red.

Leaves somewhat narrow, apex acuminate, serratures medium to deep; spines on cane short to medium, green, with frequent red tip and prominent green base; petiole with many spines; canes very tall, moderately glaucous . . . . . Cuthbert

CCC—Leaflets mostly 5.

Leaves somewhat narrow, very glossy, apex acute, serratures medium to deep; spines on cane very numerous, dark purple red, with very distinct dark purple red base; petiole with frequent short spines; canes moderately glaucous; leaflets rarely 3 . Erskine Park, La France

BB—Spines on cane medium to long, more or less flexible or bristle-like, not enlarging toward the base into triangular form.

C—Leaflets mostly 3.

D—Numerous hair-like spines on petiole.

E—Canes strongly glaucous.

Apex of leaf acuminate, serratures shallow to medium; spines on cane very numerous, green to light red with slight green base; spines on petiole medium to long . . . . Ohta

EE—Canes moderately glaucous.

Leaves somewhat narrow, apex acuminate, serratures shallow to medium; spines on cane common, green or slightly red, with no distinct base; spines on petiole long . . . . **Minnetonka Ironclad

DD—Spines on petiole not hair-like.

E—Canes strongly glaucous.

Leaves dark green, apex acute, serratures shallow to medium; spines on cane very numerous, green or slightly red, with prominent green base; petiole red, with many spines; leaflets rarely 5 . . . . . Sunbeam

EE—Canes moderately glaucous.

Apex of leaf acuminate, serratures shallow to medium; spines on cane numerous, dark red, with prominent red base; numerous spines on petiole . . . . St. Regis, Ranere

CC—Leaflets as frequently 5 as 3.

D—Numerous hair-like spines on petiole.

Apex of leaf acute, serratures medium deep; spines on cane few

**Grown under this name, no opportunity to determine whether true to name.

to common, green or slightly red with small green base; spines on petiole very short; canes moderately glaucous..............King

DD—Spines on petiole not hair-like.

Apex of leaf acute, serratures medium deep; spines on cane few to common, green or slightly red with slight green base; canes strongly glaucous .. ..Latham, Imogene, Redpath

Use of Leaf Characters in Identification of Plum Varieties*

By W. H. ALDERMAN and J. S. SHOEMAKER, *University Farm, St. Paul, Minn.*

THE WORK of Shaw and others has demonstrated clearly the value of leaf characters in identification of apple varieties. The practical application of such systematic studies with the apple has been ably demonstrated by the nursery stock certification plan in operation in Massachusetts. The difficulty of satisfactorily identifying plums commonly grown in the upper Mississippi Valley prompted the authors to make a study of the use of leaf and tree characters for this purpose. The key which has been developed as a result of this study is of value, not only in the identification of nursery trees, but also the older trees where a reasonably vigorous growth condition prevails. Since the varieties of plums now being grown in Minnesota and surrounding states are for the most part of a hybrid origin and of relatively recent introduction, the present key must be considered mainly for local use. It illustrates very well, however, the taxonomic value of the characters considered and may readily be extended to include varieties common to other regions. It should be stated that further checking of the data may bring about minor modifications in the key, but it is believed that its form will not be materially changed.

The success of the work in identification of apples by leaf characters would lead one to expect that the same principles might be even more readily applicable to plums. Apple varieties have been developed from within a single species and do not present as great a variation in leaf and tree characters as can be found between varieties of plums which have been produced from a wide range of species and include many hybrid forms. This variability among plums has proven to be of a decided advantage in the development of such a key as is herein presented. The species included in the present discussion are Prunus americana, Prunus nigra. Prunus salicina, Prunus simonii, Prunus besseyi and various hybrids between these species. The 35 varieties enumerated include most of those at present propagated and sold by nurserymen in the upper Mississippi Valley.

The material studied was selected only from vigorously growing trees. The leaves had been selected from about midway the length

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of strong growing shoots not less than 12 inches in length. It is important that this vigorous condition should be present for the foliage of weak and malnourished trees is by no means typical of normal foliage.

Serratures. One of the most constant of the leaf characters are he serratures along the margin. For instance, this character alone separates the plums considered in this discussion into three general groups: Prunus americana (including P. americana mollis), Prunus nigra and hybrids between Prunus salicina and the native species mentioned above. The americanas are readily recognized by their coarse and sharp pointed, usually double serratures. The nigra group is characterized by deep, distinctly rounded serratures, while the hybrid group referred to has serratures usually smaller, more closely set and less sharply pointed than the Americana group.

Petiolar Glands. The glands along the petiole vary somewhat within the variety. They can generally be grouped in fairly distinct classes that may be used to separate varieties. In number the glands may be classed in the following groups: seldom more than 2, 3 to 4, and 4 or more. In size the glands vary so that they may be classed usually either as large or small and therein give us a very useful character.

Size and Shape of Leaf. These conspicuous leaf characters are undoubtedly the most convenient and important of all for rapid identification of varieties when the actual key is not called into use. In passing along the nursery row one readily notes even small variations in size and form of leaves. A little experience will enable one to quickly identify certain varieties by these characters alone.

It would be well at this point to indicate a few of the outstanding characteristics in shape and size of leaves. In the hybrid group there is a peculiar leaf type designated here as "invert saucer shaped." This is a term applied to leaves which somewhat resemble an inverted saucer, but are of course long in relation to length rather than circular. "Folded downwards" or "backwards" are terms which might also be used to designate this same condition, but it seemed to the writers that inverted saucer shape was more truly descriptive of the condition. In some varieties, notably Radisson and Waneta, many of the leaves will be so strongly and sharply folded as to give rise to a term "invert keel shape." It should be understood that not all of the leaves on a tree will be thus formed, but there will be enough present to furnish a ready means of identifying a variety. These inverted leaves are generally found on the more vigorous growth. Contrasted with these types are leaves flat or folded upward. A still different form is one in which the leaves are recurved, that is, bent upward, usually most conspicuously so in the apical half of the leaf. Leaf size varies widely within a variety or on a single tree, but varieties themselves may be roughly classified as to leaf size, some constantly bearing small leaves and others leaves of very large size. The sandcherry hybrid group may be easily recognized by its small stiff leaves.

Leaf Surface. A leaf may be flat or may be deeply waved and

crinkled. The upper surface may range from a glistening appearance to a very dull finish. Leaf texture is somewhat difficult to describe, but the leaves themselves present a distinct variation in this character. Some are soft and smooth, almost satiny in finish and paperlike in thinness, while others are thick, roughened and are harsh to the touch. This roughness on the under surface is due in part to minute barbs or prickles on the under side of the veins. Fine texture is apparently nearly always associated with thin leaves and coarse texture with thick leaves.

Apex and Base. The shape of the leaf extremities is a useful character in some cases. The apex or terminal third of the leaf blade may be narrow, blunt or sharp pointed. Most varieties are listed as acute pointed, but many range strongly toward an acuminate form. The base of the leaf ranges from a broad, roundish form to tapering or cuneate.

Petiole. The length of the petiole is quite variable, but is frequently useful in identification. The most useful features of the petiole are the color, which is distinctly red in certain varieties, while in others it is green or reddish green. The groove on the upper surface of the petiole is an important taxonomic character. This ranges from wide to narrow and from deep to shallow. The edges of this groove when the petiole is taken in cross section may be either broadly rounded or narrowed to a fine knifelike edge. In certain cases pubescence on the petiole offers a fairly constant character for differentiation.

Color of Terminal Leaves. During the season when the shoot wood is still growing and new leaves are being formed, there is frequently a characteristic coloring of these new leaves, ranging from a rather deep red to a green and greenish yellow. As the leaves mature and the terminal bud is formed, this color differential generally disappears.

Shoot Wood. The vigorous growing wood possesses color differences as it approaches maturity that are frequently valuable means of identification. These range from a bright red color through reddish brown to a green. This same shoot wood in some varieties is pubescent, while in others it is glabrous.

Position and Form of Buds. Bud descriptions have not been used extensively in the attached key, but these, when studied in their winter condition, would form a valuable adjunct. In one case, the variety Loring has been clearly and easily distinguished by the fact that the buds, instead of being appressed, stand out from the shoot wood and are further characterized by a prominent bulging protuberance between the bud and the shoot.

Conclusions. The importance of some kind of classification involving a workable key for the more definite identification of fruit varieties has long been recognized. Several have been devised based upon fruit characters, but since mature fruit is available only during a short period each year, the usefulness of such classifications is limited. The work of Shaw on apples, Winter on raspberries and the present study of plums, clearly demonstrate that other plant

characters are fully as usable as those of the fruits and in some cases present more definitely recognizable differences. Furthermore, they are available during a long period of each year and equally useful in determining the identity of young nursery stock and mature fruiting plants.

Key for Identification by Means of Leaf Characters of Varieties of Plums Grown in Minnesota

I. True Plums.

A—Serratures deep, sharply pointed.
  B—Leaves woolly pubescent.
      Leaves large; petiole groove wide, edges thin .... Wolf
  BB—Leaves slightly pubescent or glabrous.
    C—Glands small to medium size.
      D—Upper surface distinctly shiny.
          Serratures rather closely and regularly spaced. Leaves medium size . . ..Terry
      DD—Upper surface moderately shiny or dull.
        E—Leaves medium size.
            Leaves broadly oval, medium thick, slightly puckered; base often wedge shaped .... .Wyant
        EE—Leaves medium to large size.
            Leaves oval, thin, smooth; base often heart shaped Forest Garden
    CC—Glands medium to large size.
        Petiole short; leaves medium to large size .. .. DeSoto
AA—Serratures deep, distinctly rounded, glandular.
  B—Leaves orbicular.
    C—Shoot wood pubescent; petiole pubescent.
        Leaves large; base often heart shaped ....Winnipeg
    CC—Shoot wood glabrous; petiole nearly glabrous.
        Leaves medium to large; base often wedge shaped ... Assiniboine
  BB—Leaves oval to broadly oval.
      Leaves medium size; base often heart shaped; petiole groove deep, narrow to medium wide, edges slightly rounded.. . .. .Cheney
AAA—Serratures shallow to medium deep, moderately pointed to rounded.
  B—Leaves usually or frequently invert saucer or keel shaped; glands medium to large.
    C—Leaves often invert keel shaped on vigorous growth.
      D—Glands seldom more than 2.
          Leaves long, rather narrow; upper surface shiny; petiole medium long, medium stout . . . . Waneta
      DD—Glands often 3-4.
          Leaves large; petiole long, thick, stout ....Radisson
    CC—Leaves invert saucer shaped.
      D—Glands seldom more than 2.
        E—Shoot wood pubescent.
          F—Shoot wood russet colored.
              Serratures shallow, somewhat rounded; petiole groove wide with thin edges near axil of leaf but becoming narrow and with rounded edges towards base of petiole; leaves closely spaced along shoot. Tonka
          FF—Shoot wood reddish brown.
              Serratures medium deep, moderately pointed; petiole groove narrow, edges distinctly rounded; leaves widely spaced along shoot.................................. ...Red Wing
        EE—Shoot wood glabrous.
          F—Groove in petiole wide, edges thin.
            G—Apex broadly acute.
                Leaves light to medium green color; medium fine texture; base moderately broad; glands usually 1 or 2..... ......Mendota

GG—Apex acuminate to acute.
Leaves medium to dark green; coarsely veined; base slightly tapering; glands frequently inconspicuous............Mound

FF—Groove in petiole narrow, edges rounded. Leaves large, broadly oval, fairly smooth, very shiny or glistening..................Monitor

DD—Glands often 3–4.

E—Buds free from shoot wood, heavy shoulder; prominent protuberance between bud and shoot wood.
Leaves long, rather narrow; upper surface shiny; serratures shallow, somewhat rounded; edges of petiole groove rather thin...Loring

EE—Buds appressed to shoot wood.

F—Petiole long; petiole groove medium wide, edges thin.
Leaves coarsely veined; serratures shallow; base tapering...Anoka

FF—Petiole rather long, thick, stout; groove shallow, wide, edges slightly rounded. Leaves coarsely veined; upper surface puckered.... Waconia

DDD—Glands 4 or more.
Leaves large, shiny; shoot wood pubescent......... ..Pembina

BB—Leaves not invert saucer or keel shaped; glands small to medium size (except in Hanska).

C—Glands seldom more than 2.

D—Leaves long, narrow; apex long, tapering.

E—Leaves medium to large size, flat or recurved, coarse texture.
Serratures medium deep, moderately pointed; underside of midrib and large veins barbate; petiole groove medium wide, edges sightly rounded ....Winona

EE—Leaves small to medium size, distinctly rolled or folded upward, fine texture.
Serratures rather shallow, rounded; underside of midrib and large veins glabrous; petiole groove narrow, edges thin..........Kaga

DD—Leaves oval or nearly so, thin, fine texture.

E—Serratures shallow, rounded.
Leaves with sides slightly rolled upward; petiole groove wide, edges thin.......................................Underwood

EE—Serratures medium deep, moderately pointed.

F—Shoot wood light reddish brown; leaves rather small.
Leaves recurved, twisted; upper surface shiny; glands greenish yellow; petiole groove narrow to medium wide, edges thin...... Golden Rod

FF—Shoot wood purplish red; leaves medium size.
Leaves inclined to be recurved; upper surface moderately shiny; glands yellowish green; petiole groove medium wide, edges thin.....................................La Crescent

CC—Glands often 3–4.

D—Leaves light green, folded upward, thin, fine texture.

E—Leaves crinkled; margins waved.
Leaves small, light yellowish green; upper surface distinctly shiny; glands greenish yellow; petiole long; serratures small, close set, dull pointed; edges of petiole groove slightly rounded; terminal leaves yellowish ....Hennepin

EE—Leaves not crinkled, margins not waved.
Leaves small to medium; upper surface shiny; glands often large; petiole short, groove narrow, edges slightly rounded; serratures medium small, medium close set, moderately pointed to rounded Hanska

DD—Leaves dark green, flat or recurved, coarsely veined.

E—Leaves small; obovate; apex acute; tip short.
Base tapering; petiole short, groove wide, edges thin, serratures shallow, rounded....................................Elliot

EE—Leaves medium size; oval; apex acuminate.
Base slightly tapering; petiole groove medium wide, edges slightly rounded; serratures shallow, moderately pointed..........Stella

II. Sand Cherry Hybrids

A—Glands seldom more than 2.
 B—Petiole distinctly red throughout season.
  Leaves small, evenly folded upwards; upper surface smooth; serratures sharp; glands often inconspicuous . . . . Nicollet
 BB—Petiole green or slightly tinged with red.
  C—Serratures widely spaced.
   Base narrow, tapering; upper surface puckered, moderately shiny; petiole groove wide, edges thin . . . .Zumbra
  CC—Serratures close set.
   D—Upper surface distinctly shiny.
    Apex acute, tip short; petiole groove wide, edges thin .....Opata
   DD—Upper surface moderately shiny to dull.
    E—Leaves folded upward, oval; petiole groove medium narrow, edges slightly rounded. Serratures medium size; leaves medium size; rather flexible; tree upright in habit of growth . . Compass
    EE—Leaves flat, ovate.
     Leaves medium thick; petiole groove deep, wide, edges thin.. . Tom Thumb

AA—Glands often 3–4.
 B—Petiole groove wide, edges thin
  Tip medium long, sharply pointed; terminal leaves yellowish green .. St. Anthony
 BB—Petiole groove narrow to medium wide, edges slightly rounded; tip frequently short and dull pointed; terminal leaves greenish .. Sapa

A Record System for Fruit Breeding Work*

By A. N. Wilcox, *University Farm, St. Paul, Minn.*

THE PRESENT method of keeping breeding records at the Minnesota Fruit Breeding Farm has certain features which have been found valuable in contributing to its reliability, convenience, and economy. One of these is the numbering system which has been used for the past 3 years.

The numbering system was arranged with the following considerations in mind: first, to provide a means of tracing the breeding history of a plant quickly; second, to prevent confusion and mistakes involved in changing or copying numbers; and third, to permit the use of brief, permanent labels stamped in zinc.

The system involves the use of 2 letters to designate the kind of fruit (usually the first and last letters of the name) followed by the number of the year, followed by the serial number of the cross. For example, the plum crosses made in 1925 were numbered consecutively beginning with PM251, PM252, etc. This number is stamped by machine on a strip of zinc, which is also punched. The label may be attached by wire to the tree or branch involved in that particular cross. The same label accompanies the cross when the fruit is picked and the seed stratified, when the seeds are planted in flats, when the

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seedlings are transplanted to the frames and later to the nursery, and finally when the trees are planted in the trial orchard. Here the trees are placed in succession in a row and the label is nailed to a substantial stake driven in front of the first tree of the cross, whether it happens to be at the end or in the middle of a row.

When it is found desirable, the trees may now be given individual numbers which consist of the cross number followed by the serial number of the tree, the two being separated by a dash. For instance, if in cross PM231 there are 17 trees, these trees are numbered consecutively from PM231-1 to PM231-17.

When it is inconvenient to attach zinc labels to branches at the time of pollination, cardboard labels are used until the fruit is picked and the seed stratified. Because this practice introduces a source of error, it is not recommended for general use. For stratified seeds and for seedlings growing in flats or in frames, a wooden pot label, with the strip of zinc wrapped around it, is used.

The fundamental breeding number is varied for different classes of material. To designate progenies which originated by self-pollination instead of by crossing, the letter S is added. In this case, grape self-pollinations made in 1924 were numbered consecutively beginning with GES241.

The method of tracing breeding records can be explained by means of the following illustration. Suppose the history of a strawberry seedling, SYS2529-7, is sought. The number reveals that this is the seventh seedling in the progeny of a plant which was self-pollinated in 1925. By referring to the 1925 pollination book, the following record may be found:

Breeding number	Parentage	Number flowers pollinated	Date pollinated	Number fruits matured
SYS251	Minnehaha x self	7	5/22/25	4
SYS2529	SY238-4 x self	3	5/28/25	2

The parent of progeny SYS2529 is here found to be the fourth seedling of the eighth cross made in 1923. By consulting the 1923 pollination book it may then be found that the progeny SY238 came from the cross Dunlap x Progressive. Hence the seedling SYS2529-7 is an individual of the F_2 generation of that cross.

Inasmuch as new introductions in all fruits are recorded in the same accession book, the numbers applied to them contain no letters to designate the kind of fruit, but simply consist of the letter N followed by the number of the year and the serial number. Thus the new introductions of 1926 will be numbered consecutively N261, N262, etc., as they are received, regardless of the kind of fruit.

The practice of assigning to the most worthy seedlings a "Minnesota number" is still followed. A separate series is used for each kind of fruit. This is the only number that goes before the horticultural public. Because of its simplicity it is preferred to the breeding number for this purpose, although the undesirability of changing numbers is recognized.

For keeping the breeding records, printed forms are used in loose-leaf binders. These provide space for recording breeding numbers, parents, crossing dates, numbers of fruits set, of seeds matured, and of seedlings raised, and such other data as may be important. Additional forms are provided for nursery records and for orchard records. There is a possibility of making mistakes, however, in transferring numbers from one form to another. Because of the danger of confusion involved in the use of loose leaves, and because of the convenience of larger pages, solid books are now being used for certain classes of notes. Sixteen column standard figuring books, cloth bound, with pages 10 by 12 inches, are very convenient, and will probably find increasing use.

It is recognized that while the record system now in use serves very well, there should be a further development, and that this development should tend toward the greatest possible simplification of the necessary records.

Report of Committee on Standardizing Intercollegiate Fruit Judging

By B. D. Drain, *Chairman, Agricultural College, Amherst, Mass.*

YOUR committee on standardizing intercollegiate fruit judging was not appointed until autumn of this year and can make only a partial report at this time.

Three of our local leagues, the Missouri Valley, Eastern Intercollegiate, and New England, together with the American Pomological Society, are all using the score card adopted by this society in 1914, with one modification. The item "Freedom from blemishes" has been changed to "Condition." This committee favors this change.

Judging Condition in Apples

The amount or degree of the trouble is quite as important as the kind. Thus scab the size of a pin head should be scored less severely than large fresh skin punctures. The following groups are arranged approximately from the more severe to the less, other things being equal.

Group I

Codling moth
Soft rot (caused by Penicillium expansum)
Railroad worm
Apple blotch
Bitter rot
Apple scab

Group II

Worm injury (various kinds as lesser apple worm)
San Jose scale
Storage scald
Withering (including shop worn)
Unhealed skin punctures
Unhealed growth cracks
Red bug damage

Group III

Baldwin spot
Jonathan spot
Physiological breakdown
Water core
Heavy bruise (skin not broken)
Curculio damage
Black rot
Sooty fungus
Cedar rust
Over ripe (slightly)

Group IV

Entire absence of stem
New England fruit-spot (caused by Phoma pomi)
Fruit spots (unidentified)
Small insect stings (healed)
Hail damage (slight)
Small red spots not caused by scale
Slight spray russeting
Small rub spots (caused by limbs and twigs)
Slight russeting (cause unknown)
Small packing bruises
Insect eggs (example European red mite eggs)

This rating involves 2 things: (1) Marketability of the fruit and (2) index of the growers' methods as reflected by the specimens in question.

For example; a few San Jose scales have little influence on the marketability of the fruit, but reflect on the growers' methods.

Work has been started on such questions as a score card for intercollegiate pecan judging, size standard for apples and the like, but we are not ready to report on these items at this time.

Scoring and Judging Fruit Displays

By S. H. HOLLISTER, *Agricultural College, Storrs, Conn.*

PRESENT methods of exhibiting fruit are quite different from what they were 20 or 50 years ago. We are tending toward uniform standards, although some organizations still hold to the platter of 12 specimens, or a plate of 10, etc. The early displays or exhibits were local, the grower had some nice fruit which he wanted his friends to see and enjoy.

From this small beginning the idea of local shows, state shows and national exhibitions developed. Consequently the principles of uniform numbers and uniform sizes of both fruit and packages have been worked out. Fruit exhibiting is now almost an art, we might almost say a business, for there are so called "professional exhibitors." We are all familiar with the small local fair which has a "fruit department," where a certain amount of space is to be filled with fruit. The state fair has a more extensive exhibit, while the pomological or horticultural society may have an exhibit composed entirely of fruit.

To "run" or "put on" a successful fruit show or exhibit, the following items should be considered, not all of which perhaps carry the same weight, but arranged somewhat in the order of attention. They are:

1. Arrangement of premium list.
2. Advertising.
3. Preliminary work in the exhibition hall.
4. Arrangement of the exhibits.
5. Labeling.
6. Judging.

One could write an article on each of the above headings, but in this short paper I will only mention briefly a few points which I feel should receive more attention by those who are directly interested in improving conditions at our fruit exhibits.

PREMIUM LIST

The premium list should be in the hands of the growers weeks and months, rather than days, before the show is to be held. This allows time to make plans, select and pack fruit, etc. A grower might even be induced to do a better job of spraying if he became interested in getting "show fruit."

More definite directions should be given the exhibitors regarding the packing, nailing, labeling, and opening their exhibits. One grower packs a barrel and does not nail it at all, assuming it will be easier to inspect. This barrel is in competition with a barrel which was packed and shipped. Shall boxes brought to the show with risers compete on the same basis as boxes packed without risers?

ADVERTISING

The growers should be well informed in regard to the coming fruit show, for we depend upon them to provide the fruit. We should

not, however, forget the public. Feature articles are very popular; have the local papers print stories about the orchards of the community, stating that John Jones will exhibit in competition with Ben Burke, etc. In towns and cities more local advertising should be done at the time of the exhibition using placards, hotel advertising, street cars, etc.

Preliminary Work in the Exhibition Hall

Tables and racks should be waiting for the exhibitor—not the exhibitor waiting for the carpenter who stops work when the whistle blows. The system of having entries close a few days before the opening of the show should give the management enough time to provide staging, etc In many cases the manager is hampered by lack of assistance.

Display tables should not be too wide. Mass effect of fruit is beautiful but for close observation the narrow table is to be preferred. Aisles should be generous; 10 feet is about the minimum width.

Arrangement of Exhibits

The rule which states that exhibits shall be in the hall and in place at a definite time should be closely followed.

Any fruit exhibit naturally divides itself into groups or classes such as the plate collections, single plates of apples, pears, peaches, plums, etc., boxes, barrels, special exhibits, etc. It goes without saying that the exhibits of the various classes should be together. When possible, plate collections such as 5, 10 or 15 commercial varieties, should extend lengthwise of the table; thus the varieties which appear in each collection can be placed together, and the odd varieties can more easily be compared.

Many premium lists make different classes for plate varieties. Those which are considered most valuable are placed in a group upon which a higher premium is awarded, less valuable varieties in another class, etc. This arrangement is probably very satisfactory for the management, but for the public it is confusing. I believe varieties should be arranged alphabetically. This should apply to all plate exhibits. The day of having each grower's fruit by itself has largely passed.

Labeling

Too few plainly printed explanatory labels are used. Placards such as Class III, Group V, are all right when setting up the exhibit, but they mean nothing to the public. "Best Five Varieties of Com mercial Apples," is better than Class IV, Group V. Visitors care very little about the particular classification, but they do want to know the names of the varieties, whether a bank of fruit is all from one grower or whether it is from several. They want to know what the premium ribbon is awarded for. As far as possible each variety in each class or collection should be designated.

Judging and Scoring

The public is interested in the fruit exhibit or display itself, but the growers and students of pomology are interested also in the judging. Often the friendship of a grower may be lost by unsatisfactory judging. I do not mean that the grower or exhibitor expects awards on all his fruit, but the manner in which the judging is done is most important.

The judging should be of such a character that an open-minded exhibitor will be satisfied, that he will feel that the judging has been honest and thorough. As I mentioned before, the show depends upon the grower; hence in a way, the success of future shows depends upon the judge.

Judging is a big factor in any fruit show. Why is it that it does not receive more publicity? We have all seen the crowd watching the judging of cattle and horses. It makes little difference whether it is hot or cold, the people are there. Special areas are fenced off, tents and seats are erected so that the interested people can watch the judging. What are the conditions at most fruit shows when the judging is being done? Briefly stated, the public is asked to "stand back" while the judge or judges handle the fruit, inspect the packages and make their decision. Often an aisle is fenced off, and visitors to the show may see a man handling the fruit and when some curious person asks what he is doing, the answer comes in abated breath "the judge is judging." This condition should not exist. The growers, exhibitors, students of pomology and others, should have an opportunity to watch the judging of fruit in a similar manner to that of judging livestock.

There are several methods which can be used to a greater or less degree so that those interested can see the work done and hear the remarks of the judges.

(1). In many cases I believe it will be possible to have a judging area with space allotted to the visitors. The judge should be required to give his reasons for making certain awards. This will put the judge on his mettle and he will have to make quick and accurate decisions.

(2). Another method of increasing the efficiency of the judging is by the greater use of the score card. This applies not only to the fruit in packages but in collections. It ought not to be necessary to go over an exhibit more than twice, if a score card is carefully used.

(3). More judges will have to be provided. It is unwise to expect 1 or 2 men to judge the fruit at the larger expositions. Enough judges should be provided in order that the work may be completed within a few hours after the show opens. Visitors are anxious to know who receive the awards.

(4). More assistants should be provided for the judges. Whenever possible, the judge should be seated at a large table and the fruit placed before him. There he will make his awards under the same conditions of light, heat, etc.

(5). The responsibility of seeing that all exhibits in a class are judged should rest with the management, not with the judge. Too

much time and energy are often expended by the judges in "locating exhibits."

(6). Special exhibits and displays should be judged by the use of special score cards. Judges should follow the premium outline or the written statements from the committee when judging any group or class.

Judges

I believe commercial exhibits should be judged by a committee consisting of at least one institutional man, a progressive fruit grower, and a reliable dealer. By this method the problems of the grower are considered, the value of the fruit and packing are discussed from the trade standpoint and the finer points on packing and quality are not overlooked if an institutional man is present.

Summary

Fruit exhibits are appreciated by the general public. It brings the different growers into cordial rivalry. The success of the fruit exhibit depends upon a well organized management which takes into consideration the early publication of a premium list, seeing that the show is well advertised, in having enough available labor so that the preliminary work in the exhibition hall is completed ready for the exhibitors to display their fruits. It is important that the plate exhibits be arranged alphabetically and that the commercial packages and special displays are easily accessible to the judges. Labeling should be plain, complete but not over-conspicuous. The judging should be done by competent, well-informed, unbiased men who will work under conditions which will allow the public to watch their methods and hear their remarks. The judging should, as far as possible, be educational and instructive.

Government Inspection of Nurseries to Eliminate Variety Mixtures

By W. H. Upshall, *Vineland Station, Ontario, Canada.*

THE SYSTEM of identification of apple varieties in the nursery row established by Dr. Shaw, suggested the possibility of a similar system with the other tree fruits. For the past 3 seasons the writer has carried on similar investigations with pears, plums, cherries and peaches at the Horticultural Experiment Station, Vineland, Ontario. The final result has been that this year practically all the salable stock of fruit trees grown in Ontario has been inspected and rogued for variety mixtures.

There has been much discussion about the advisability of depending upon leaf and other growth characters in the identification of varieties of tree fruits. Because of the wide variations noted under

different conditions there has been a tendency to attach little importance to these characters. A survey of these reports shows that studies have been made mostly on bearing trees, which, on account of pruning, fertilizing or fruit-bearing, exhibit varying degrees of vigor with attendant variations in growth characters. On the other hand, nursery trees have been treated similarly and usually show a fairly uniform degree of vigor; for this reason the nursery row seems to be the best place for a study of this kind.

Of necessity one must check up on the varieties in the nursery row to make certain that all are true to name. This can be done in at least three ways. (1) Comparing the same varieties in a number of nurseries. (2) Checking up on the identity of fruit produced on trees from which bud sticks were taken. (3) Comparing leaf and growth characters of the nursery trees with those of young vigorous orchard trees, which having borne fruit, are known to be true to name. In the latter case an old orchard tree is not desirable because its growth habit and leaf characters may have become modified by fruit bearing or pruning. Even in a young bearing tree in order to get conditions of vigor comparing at all favorably with those occurring in the nursery row it is necessary to examine shoots at the top and central portion of the tree. In all the tree fruits leaves typical of the variety can be obtained only about half way along the young shoots, and usually identification of varieties in the nursery row is possible when the earliest shoots have attained a length of 10 or 12 inches.

It is not possible in this paper to give a complete list of growth characters useful in the identification of varieties and, therefore, only the basis of classification with a few notes of major importance will be included. Only the more important varieties grown in Ontario nurseries are classified. The system of identification outlined by Dr. Shaw was followed in the inspection of apple varieties. In some cases, the characters appearing in the following classification, being somewhat variable, must be used with caution and only in conjunction with other characters.

PEARS

A-Shoots red	B-Shoots green or brownish
1. Clairgeau	1. Bartlett
2. Duchess	2. Anjou
3. Howell	3. Sheldon
4. Kieffer	4. Bosc
5. Seckel	
6. Clapp	
7. Flemish Beauty	

Among these varieties of pears Kieffer is distinct because of the presence of brownish pubescence near the tip of its shoots. If the other varieties listed possess any pubescence on their shoots it is always greyish in color. Leaf characters of major importance in identification are shape, folding, the character of the surface and of the serrations, and these characters, difficult to describe without photographs, are used to distinguish varieties within the 2 main groups.

Plums

A—Shoots smooth (glabrous)
- (a) Tip leaves pink or light green
  - xGlands usually on petiole
    1. Abundance
    2. Red June
    3. Burbank
    4. Shiro
    5. Bradshaw
    6. Lombard
    7. Pond
  - xxGlands usually on blade
    1. Grand Duke
    2. Yellow Egg
- (b) Tip leaves dark red
  - xGlands usually on petiole
    1. Fellenburg
  - xxGlands usually on blade
    1. Coe Golden Drop
    2. Reine Claude
    3. German Prune

B—Shoots Pubescent
- (a) Tip leaves pink or light green
  - xGlands usually on petiole
    1. Imperial Gage
  - xxGlands usually on blade
    1. Shropshire Damson
    2. Washington
    3. Arch Duke
- (b) Tip leaves dark red
  - xGlands usually on petiole
    1. Glass
  - xxGlands usually on blade
    1. Field
    2. Shipper Pride
    3. Monarch
    4. Gueii
    5. Diamond

The primary basis of classification of plum varieties on absence or presence of pubescence on the young shoots and especially near the tip, is absolute and definite. Under varying conditions the amount of pubescence will vary, but a variety having normally pubescent shoots is never without some pubescence which can readily be seen with the naked eye. The further classification on color of tip leaves and position of foliar glands must be used with care. Though these characters are somewhat variable yet they are stable enough to warrant some recognition. Other gland characters such as shape, size, color and number, are not very dependable.

Cherries

1. **Sour Cherries**

Early Richmond Montmorency (a comparison)	1. Montmorency has a more upright growth habit. 2. There are fewer lenticels at the base of the shoots of Montmorency. 3. The older leaves of Montmorency have a dull green color while Early Richmond shows a shiny green.
English Morello..	....is distinct from the other two in its more rotund, thicker, grey green leaves.

2. **Sweet Cherries**

A—Young petioles smooth (glabrous)
 1. Bing—leaves shiny.

B—Young petioles pubescent
 1. Black Tartarian—glands small, reniform and pale in color.
 2. Napoleon—glands small, round and pale in color.
 3. Schmidtz—glands near the blade, dark red in color and spread well apart.
 4. Lambert--glands irregular in shape; bark dark in color.
 5. Windsor—glands irregular in shape; reddish cast to bark color.
 6. Governor Wood--glands large, reniform and dark red.

The character of smooth young petioles in Bing is constant under all conditions and is an easy means of identifying this variety. Republican is the only other variety noted which possessed the same character and as Bing is supposed to be a seedling of this variety, here is further evidence to verify its origin.

Observation has shown that the foliar glands on sweet cherry leaves are less variable in the early summer than later in the season, therefore, it is advisable to inspect nursery stock of this fruit as early as possible. In any case it is advisable to inspect both sour and sweet cherry stock early in the summer because of the danger of aphids attacking them and so distorting the leaves that identification is rendered impossible. The characters of the lenticels are very useful in separating varieties of sweet cherries; for instance, Schmidtz has many very large and prominent lenticels while on Windsor the lenticels are few, small and inconspicuous.

Peaches

A—Absence of Yellow Pigment in Leaves (White-fleshed)
 (a) Globose glands
  1. Alexander
  2. Champion
  3. Mayflower
  4. Mountain Rose

(b) Reniform glands
1. Belle of Georgia
2. Carman
3. Greensboro

B—Presence of Yellow Pigment in Leaves (Yellow-fleshed)

(a) Globose glands

xLeaves very crinkly
1. Brigdon (Garfield)
2. Early Crawford
3. Fitzgerald

xLeaves not much crinkled
1. New Prolific
2. Niagara
3. Reeves Favorite
4. St. John
5. South Haven
6. Triumph

(b) Reniform glands
1. Admiral Dewey
2. Arp
3. Beer Smock
4. Elberta
5. J. H. Hale
6. Lemon Free
7. Rochester
8. Yellow Swan

(c) Intermediate glands
1. June Elberta

There is a marked correlation between color of fruit flesh and presence or absence of yellow pigment in the veins of the leaf. Strictly speaking the yellow pigment may not be entirely absent in the leaves of a white fleshed variety, but certainly it is very abundant in the leaves of a yellow fleshed variety and the distinction is unmistakable. Often the flesh color of the fruit can be determined by mere observations on the shade of green in the foliage, but in case of doubt a healthy mature leaf which has been well exposed to the sun's rays should be picked and held up to the light for examination.

The gland classification of peach varieties has been questioned by various authorities—Gregory (1), Hedrick (2) and Connors (3). After an examination of hundreds of bearing trees and many thousands of nursery trees, including some 40 varieties, not one has been found having a mixture of reniform and globose glands. This is in accord with Connor's observations, but, as his breeding work has shown, there is a possibility of a seedling with one type of gland being mistaken for one of its parents with another type of gland. This would happen only when a variety produced a seedling very similar in fruit characters to itself. As it is very difficult to distinguish all peach varieties by their fruits, it is quite possible that most or all

of the irregularities reported within varieties in regard to gland type, were due to mistaken identity.

One variety, June Elberta, has an intermediate type of gland situated at the base of the blade which resembles both the globose and reniform types. This has been the only variety noted having this type of gland and, therefore, it is an easy one to identify.

There is so little difference in growth habits and bark characters in peach varieties that little use can be made of them in distinguishing varieties, and, therefore, one has to depend almost entirely on shoot and leaf characters. Many of the varieties, such as those of the Crawford type, are so closely related that it is almost impossible to distinguish them. Nevertheless, if a nurseryman knew the foregoing classification of peach varieties he would be able to pick out a large percentage of the varieties untrue to name in his nursery rows. In Ontario there is approximately an equal number of varieties having each type of gland, viz., reniform and globose, and possibly one quarter of the total number are white fleshed varieties. It follows then that, mixtures occurring according to the law of chance, at least three-quarters of them should be found. An experienced inspector could locate other mixtures by means of other leaf characters.

During the summers of 1923 and 1924, inspection of nurseries was done only in a small experimental way, the object being mainly to become familiar with the appearance of the more important varieties and to work out a system for their identification. As a result, this past spring the Ontario nurserymen were offered an inspection service on the following terms:

1. The inspection service is free to all Ontario nurseries growing the kinds of fruits noted (apples, pears, plums, cherries and peaches) in commercial quantities.

2. The nurseryman is free to accept or reject the inspection service as he sees fit.

3. The inspection service generally will be confined to recommended standard varieties.

4. The nurseryman agrees to the breaking down by the inspector of trees untrue to name. Exceptions may be made where the mixture itself occurs in appreciable quantity and where its varietal name can be determined. In such cases the inspector may, at his discretion and at the nurseryman's request, attach the proper label to such trees, labels to be supplied by the nurseryman.

5. On completion of the work an inspection certificate will be issued to the nurseryman certifying that certain kinds and varieties of fruits have been examined and found apparently free from mixture as the stock stands in the nursery row. Nurseries may advertise such inspected stock.

6. No information concerning any nursery will be given by the Inspector to any other nursery firm or private individual.

On these terms most of the Ontario nurserymen accepted the inspection service. As a result 856,100 salable fruit trees have been inspected by the writer in the summer of 1925 and are now declared

to be true to name as they occur in the nursery row. This number was divided as follows—Apples, 490,000; pears, 54,600; plums, 108,-000; cherries, 52,500; and peaches, 151,000. Amongst all these trees the mixtures amounted to about 13,000 salable trees or 1½ per cent of the total. Considering the opportunities for error in the nursery operations this is a remarkably good record. Based on total salable stock, the lowest percentage of mixtures in any nursery was three-tenths of 1 per cent and the highest, 13 per cent.

Because the average percentage of mixtures in all nurseries is such a low figure one may question the value of this inspection service. For that reason a few figures on varieties untrue to name may prove interesting. These figures have been selected from the reports sent to each nursery firm and are representative of some of the more important errors. With 4 exceptions, viz., J. H. Hale, Montmorency, Bradshaw and Salome, all these varieties were totally untrue to name in the nursery row.

PEACHES	—490 J. H. Hale were Rochester } interchanged in budding or record taking.
	480 Rochester were J. H. Hale }
	355 Yellow Swan were June Elberta
	846 Greensboro were Rochester
	532 J. H. Hale, of which only 49 were true to name
	186 Beers Smock were Late Crawford
CHERRIES	—186 Early Richmond mixed in Montmorency
	267 Bing were Schmidtz
	793 Schmidtz were Black Tartarian
	311 Black Tartarian were Black Eagle
	170 Lambert were Bing
	179 Napoleon were Schmidtz
PLUMS	—985 Purple Egg mixed in Bradshaw
	641 German Prune were Fellenburg
APPLES	—725 St. Lawrence were an unknown variety
	300 Wealthy mixed in Salome

Most of the above irregularities occurred through mistaken identity in the trees which were the original source of bud sticks. This appears to be the most common source of error in the nursery operations. These results have impressed very forcibly upon our nurserymen the wisdom of taking the utmost precautions to make sure that certain trees are true to name before bud sticks are taken from them.

Some of these mixtures had been prevalent in these nurseries for a number of years and it is safe to say that in the spring of 1926 a large percentage of these trees would have passed out to the grower under incorrect names. Some nurserymen were aware of the presence of certain mixtures which they themselves intended to remove, but it is interesting to note that this was not true in a single instance appearing in the foregoing list.

Inspected trees have been certified true to name only as they stand in the nursery row and there still remains the possibility of error at the time of digging and packing. However, there is good evidence to prove that most mixtures are likely to occur in the operations of bud-

ding, grafting and planting. Under this system of inspection all mixtures occurring in the nursery row have been eliminated at a cost to the Government of a fraction of a cent per tree. Even though some errors may occur after digging much has been done to protect the nurseryman's reputation and to assure the fruit growers of varieties true to name.

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Notes on Hardy Orchard Cover Crops*

By R. J. Barnett, *Experiment Station, Manhattan, Kansas.*

MANY years of experience and experiment have convinced the writer that the correct management of the soil on which his orchard is grown constitutes the principal problem of the apple grower in many of the apple producing sections. When one sees orchards which are well pruned and sprayed giving annual acre yields of only 200 bushels of fruit over a 5 year period and contrasts this with records in the same valley of 1000 bushels per year over a like period, the importance of this phase of orchard work is driven home. Apple trees can be grown on comparatively light soil, but long life of the tree and high yields of fruit are correlated with an abundance of plant food and the incidence of favorable soil moisture conditions.

Barn yard manure and mulches of other organic materials, nitrogen from chemical sources, and cover crops have been the correctives relied on for orchard soil improvement. Animal manures and even crude straw are increasingly difficult to obtain in most apple regions although those located near large cities or stock feeding yards can still obtain adequate quantities; chemical nitrogen is available in adequate quantities, but is high in cost; cover crops are thus forced on the attention of those who realize the relation between soil fertility and fruit yields.

Beginning with Dr. L. H. Bailey's notes published in 1893, American literature on the general subject of the use of cover crops for the improvement of soils under intensive management, has been voluminous. The types and species of plants to use, the rate and time of seeding, and the more or less theoretical benefits following their use have been the most commonly discussed phases of the subject. A bibliography containing about 100 titles of significant papers could be compiled, but will not be given or abstracted at this time.

*Contribution No. 66, Department of Horticulture.

Five years of experimental work with cover crops on the Station farm at Manhattan, Kansas, constitute the principal basis for the following notes. The soil of this 30 acre apple orchard is naturally thin and is for the most part underlain by glacial morain gravel at a depth of 1 to 3 feet. Plant food in sufficient quantity to grow trees is found in this soil, but it is not abundant enough to make the production of good acre yields of fruit probable. The trees vary in age from 10 to 15 years and 21 trees constitute a plot.

The cover crops which have been tested in these experiments are wheat, rye, Canadian field peas, soy beans, cowpeas, and winter vetch. The number of crops of each grown varies from 1 to 6 and the area seeded to each crop was never less than 1 acre and in some cases as large as 10 acres. The time of seeding has been varied between July 17 representing the earliest date and October 15 on which date wheat was planted in a time-of-planting test. Except in the case of winter vetch the rate of seeding has been unvaried during these experiments. These rates per acre were Canadian field peas 60 pounds, wheat, rye, soy beans and cowpeas 6 pecks, and winter vetch 20, 30 or 40 pounds. The time of plowing under of these crops constitutes the most perplexing question connected with their production. In the case of the winter tender crops 3 stages might be suggested for plowing: namely, just prior to the first killing frost, subsequent to the first killing frost, and an early date the following spring. Hardy cover crops were not turned under until after they had made some spring growth, but these dates were varied widely during the experiments.

Alfalfa as a perennial cover crop was tested but quickly abandoned because of its ill effects on the orchard trees. These trees were injured by the alfalfa in 2 important ways. First the buffalo tree hopper, an insect pest of the alfalfa, lays eggs in the twigs of fruit plants to their great detriment and, second, the soil moisture was adequate for both the trees and the alfalfa for only a few days after each rain. The resulting tree growth following the plowing of the alfalfa sod was also disappointing. The majority of the trees in these plots were more or less permanently weakened.

Some Preliminary Results

Several of the problems mentioned in the preceding paragraphs are still under investigation and only incomplete answers to them can be given at this time. For others fairly satisfactory results, as far as they are applicable to this district and those of like climatic and soil condition, have been obtained.

Of the crops tested, rye and winter vetch appear to be of greatest value. Wheat is so subject to attacks by the Hessian fly, unless it is planted late, in which case its fall growth confers little or no benefit, that it is ruled out. The tender legumes have given variable results when measured by the yield of dry matter and other less definite effects on the soil and trees. Yields of Canada field peas and soy beans (dry basis) have been consistently low, but cowpeas give

yields closely proportionate to the soil moisture supply. Canadian field pea seed is difficult to obtain in this district.

The effects on the trees indicate that the time of planting any of the cover crops should vary from year to year. In the station orchard where these experiments were conducted, the soil moisture relation is the outstanding factor affecting the vegetative growth and the size of the fruit produced. When July and August are dry months delay in planting the cover crops is indicated, but an abundance of rain during August, as in 1924, produces a condition under which the fall effect of the cover crop in lessening secondary fall growth and the setting of lateral fruit buds on current twig growth, is very desirable. Time of planting needs much additional invesitgation, and of a quantitative character, before definite recommendations can be made.

Rate of seeding was deemed an important question only in the case of the winter vetch. This phase of the project has been completed. The findings were that, seeding at the rates mentioned, dry matter produced was in proportion to the seed sown. If organic material is of value, it can be obtained more economically from planting 40 pounds of winter vetch seed per acre than from a 20 or a 30 pound rate of seeding.

Cover crops affect the physical condition of the soil. These experiments show that the legumes all leave the soil more friable and with a higher per cent moisture content than do the cereals. The legumes also appear to decay more rapidly than the cereals when plowed under at stages of equal succulency though accurate determinations of this action under field conditions have not been attempted.

Attempts have been made to determine the effects of the various cover crops on the vegetative growth and yield of the trees, but conclusive results have not as yet been obtained although soil analyses show wide differences in soluble nitrates on this basis. It might be added also that 6 years' work with commercial fertilizers in this same orchard have shown no positive results in favor of nitrogen, phosphorous, or potassium, either singly or in combination. Differences in response of the trees are but little greater than the probable error.

Two phases of experimental field work with cover crops seem to be especially insistent in their demand for solution. The first of these is, at what stage of development should hardy cover crops be plowed under in districts where the soil moisture content is likely to become the limiting factor in tree growth during May and June. Some data bearing on this question have been collected, but they are difficult to interpret and are as yet inadequate. The second phase relates to standardization of methods of measuring results obtained. If significant differences exist, it does not seem as though nitrate and moisture soil determinations and the ordinary fruit, twig, and trunk-girth measurements of the trees, are sufficiently refined to detect them. However, it is clear to any observer that the treated trees have been benefited.

Certain principles do seem to have been established for this district, and those having similar characteristics, by these experiments. First, cover crops are of principal value in the *young* orchard. Second, hardy crops, especially winter vetch and rye, give better average results than do tender or half-hardy plants. Third, the effects of soil ammendments of any kind are frequently masked by the moisture relation as shown by the consistent leadership of the straw mulch plots which have been run parallel with the cover crop and commercial fertilizer experiments. And, fourth, leguminous cover crops leave the soil in better physical condition than the cereals and are an economical source of the needed soil nitrogen compounds.

TABLE I—RATE OF SEEDING WINTER VETCH, AVERAGE YIELDS FOR FOUR YEARS

Pounds of seed per acre	Yield in pounds air-dried tops	Estimated nitrogen in tops pounds
20	4460	141.82
30	5008	159.25
40	5750	182.85

TABLE II—AVERAGE YIELDS FROM COVER CROPS

Crops	Pounds per acre, air dried tops	Estimated nitrogen in pounds
Rye	3356	35.97
Wheat	3263	32.35
Winter Vetch	4752	151.11
Canada Field Pea	1875*	45.25
Cowpea	4738	146.40
Soy bean	4149	106.18

*One year only.

TABLE III—WATER SOLUBLE NITRATES IN SOIL, POUNDS PER ACRE

Cover crop	Datse 1925						
	April 17	May 16	June 20	July 18	August 14	September 18	October 16
Rye*	25	48	50	312	147	132	116
Winter Vetch†	132	124	148	450	275	200	378
Check	115	116	150	190	175	325	578
Straw mulch	118	76	147	252	183	225	300

*The rye cover crop was plowed under April 20.
†The winter vetch was plowed under April 29.

Research in Vegetable Gardening

By H. C. THOMPSON, *Cornell University, Ithaca, N. Y.*

RESEARCH in vegetable gardening is relatively new, and because of this fact we have the opportunity largely to map out our own course. Before doing this, it seems to me, we should determine what are the needs in this important field. I believe it is the duty of the department group to consider all of the problems in the various branches of the field the department covers, and then to attempt to shape the research program on the basis of these problems. In this paper I propose to discuss the methods of determining what the problems are; then to list what seem to me to be some of the most important ones, and finally to discuss the various methods of attack.

Since most of us are employed by public-supported institutions, we are under obligations to render specific service to the public. In the case of research men this service is mainly the solution of problems. It seems to me, therefore, that we should make some effort to find out what are the most important problems in our field before making up our research program. Most of us are inclined to take up some problem in which we are personally interested without giving much consideration as to its importance to the public. By a little study of the needs of the industry we can find problems of interest and value to the public, and at the same time, satisfy our personal desires. It would not be necessary to change our methods of work, but merely to apply them to a different problem.

How are we to determine the important problems? I believe we should first take an inventory of our industry, at least in the state in which we are working. This would show the relative importance of the various crops produced Then we should determine, or attempt to determine, what problems are the most important considering the value of the crop and the number of persons that would be interested in the results of our work. This can be done by first-hand study of the industry by members of the staff, by consulting groups of growers representing the various branches of the industry, and by a study of the questions and problems that come to us through the extension men and through correspondence. Information secured from all of these sources should be considered in building up a program. We cannot depend entirely upon the growers for the information needed because very often they see only the most obvious things, and some problems they do not see at all. The most obvious are not always the most important. The extension men have an excellent opportunity to find out what research work is most needed, and the investigator who does not consult them is missing a good opportunity. The main point is to find out what the problems are, by all the means available, before making up a program.

WHAT ARE SOME OF THE IMPORTANT PROBLEMS

The problems mentioned in this paper may not be the most important, and it may not include all of them, but it does include some

that I think are important. No attempt is made to list them in the order of their importance.

Variety Problems: I believe all will agree that the old type of variety study did little to help solve any problem. Most of those studies were not thorough enough nor carried on long enough to be of any particular theoretical or practical value, and they gave a black eye to variety studies in general. I believe, however, that it will be conceded that we need a thorough study of varieties of all important vegetable crops. This should include technical descriptions of all known varieties and classification into groups and sub-groups. Stuart's work on varieties of potatoes and Tracy's on lettuce, beans and peppers, are illustrations of the type of studies needed. This type of study is of interest to the seedsman, to the produce dealer, the grower, the teacher and research man, and to the consumer, although the last mentioned may not know it. Variety description and grouping is one of the essentials to variety standardization so important to any improvement in marketing. During the past few years, and especially during the past year, we have talked a great deal about reducing the number of varieties, or, at least, variety names. One of the difficulties encountered here is the lack of any standard. Before we can do much along this line we must know what the varieties are. During the past 25 years quite thorough varietal studies have been made on five vegetables. If this rate continues for 300 years we will have most of our vegetable crops described and classified, provided, of course, no additional crops become important.

Soil Management Problems: What is meant here is the management of the soil with reference to applications of fertilizer ingredients, soil reaction, humus supply, crop rotation, soil toxins, etc. This general problem is one of the most serious confronting growers everywhere. With some growers, one phase of this problem is very important, while with others it is a different phase. In very intensive vegetable gardening all phases are likely to be important and more or less connected. The difficulty of maintaining production with a decreased manure supply is one of the most important problems confronting market gardeners who have, in the past, depended largely upon manure to supply both humus and nutrients.

The research work on this general problem has consisted mainly of studies of some parts of it. In most cases, fertilizer experiments have included a study of the effects of varying quantities of manure and fertilizer ingredients on yield. Some have included green manure and cover crops, lime and crop rotation along with the manure and fertilizer experiments. This makes such a complicated problem that it is very difficult to interpret the results and yet that is exactly the problem that confronts the grower. He seldom grows one crop year after year on the same land so it is important for him to know the effects of one crop on another in order to use fertilizers, manures and lime intelligently, and to plan a good system of rotation. We need to know the effects of all of the treatments given on the hydrogen-ion concentration and the effects of this on the availability of the various

nutrients as well as on toxicity. The research results at the Rhode Island Station on this problem are very illuminating and indicate how complicated it is. When the soil is quite acid there appears to be injurious effects from toxic aluminum compounds and yet when enough lime is applied to overcome this they have found that chlorosis develops. And this happens before neutrality is reached. Other results secured at the Rhode Island Station show the effects of certain crops on the yield of others which follow and some possible explanation for the difference found.

It seems to me that we will never accomplish what we should in these soil management studies until we determine the parts played by the various factors involved. For instance, we need to know the various ways in which manure affects the soil and the crop. Perhaps it has some action we have not hitherto ascribed to it. We need to take it apart. We need to consider all of the other factors and the ways they affect the crops and then determine which factors are responsible for a specific action. To solve any phase of this soil management problem, all others need to be considered. A carefully planned and thoroughly executed nutrition study on one crop might show the effects of the various treatments on that crop, but the results might be very different were that crop grown in rotation with others. In other words, a treatment recommended on the basis of a nutrition study of one crop might not be recommended at all if several crops had been grown in rotation in the same experiment.

I think we need the very elaborate field experiments in which most of the factors are considered, then we need similar kinds of field experiments in which one of the factors is taken up at a time. In connection with both of these, there is great need for carefully planned experiments under controlled conditions, and also for thorough laboratory studies. Perhaps the order of study should be reversed, but the order given is the way I think of attacking a problem. Even with all types of studies mentioned our interpretation may be incorrect, but it would be more nearly correct with all 3 types than with any one alone. Our observations are not always accurate and our reasoning is often inaccurate even when we have a knowledge of the principles involved in a given response of the plant. Our reasoning is more likely to be accurate when we understand the principles involved.

Plant Improvement Problems: The opportunity for important research work in improvement of vegetables through breeding and selection is almost unlimited. Many of our varieties are very low in edible quality and this must have a depressing effect on consumption. Suppose we had no commercial variety of apple but the Ben Davis, what would be the effect on consumption? We would probably eat something else. With many of our vegetables some of the important varieties are of the Ben Davis quality. They are grown not because they are good to eat, but rather because they are fairly presentable after being in transit for several days and exposed for sale under adverse conditions for a few more days. There are excellent opportunities to breed quality into vegetables to the great advantage of the

grower and of the consumer. Quality must be combined with other factors as yield, attractive appearance, and ability to withstand handling.

There is need for development of varieties and strains for special purposes as for canning, drying, preserving and pickling. This is important for both fruits and vegetables and the opportunity for valuable contributions is obvious.

Perhaps no more important field of breeding exists than the breeding for resistance to diseases, to insects and to various unfavorable environmental conditions. Growers and even pathologists know of no practical way of controlling many very serious diseases of plants except by the development of resistant strains. The practicability of developing disease-resistant strains is well illustrated by the work of Jones in producing a yellows-resistant cabbage; by the work of Norton in producing a rust-resistant asparagus, and by the work of Pritchard and others in producing wilt-resistant tomatoes. The work by Smith, McClintock and others at the Virginia Truck Station in developing a type of spinach which is distasteful to plant lice and because of this is protected against spinach yellows is an illustration of a method of controlling certain types of diseases carried from plant to plant by insects. Practically all of our vegetable crops are attacked by some serious disease which either cannot be controlled or which it is impractical to control by ordinary means. Development of disease-resistant strains is the problem solution. In all of this work there are excellent opportunities for genetic studies as well as the solution of practical problems.

Ecological Problems. Some of the problems mentioned under soil management are ecological in the broad sense, but the relation of the plant to other environmental factors has been given relatively little study. What little I know about this problem leads me to believe that it is a good field for study. It is well known that certain localities are well adapted to the production of certain crops, but we do not know the environmental factors that are responsible for this. We also know that in some seasons a given crop can be grown satisfactorily in a region while in other seasons it cannot, but we do not know the reasons. For example, we can grow cauliflower to perfection some years at Ithaca, N. Y., but most years we are unable to produce a crop. We do not know why this is so, but we ought to attempt to find out. In sections of New York State, lettuce is produced to perfection in some seasons and in some parts of practically every season, while at other times the crop is a failure. When only a few casual observations are made we can offer satisfactory explanations, but if we make observations several times each season and through a period of years, we find that we know very little about it. It seems to me that a thorough study of the environmental factors under which a crop grows well might be of great help in determining the reasons for failure elsewhere. At least such information as we would get from studies of this kind might give us a good clue as to the type of careful experiments we should make under controlled conditions. It has

occurred to me that data on rainfall, light intensity, air and soil, temperature, rate of evaporation and soil moisture, might be of great help in determining the factors responsible for good or poor crops in a given region. It has been shown that the yield of cabbage in New York is correlated with rainfall during certain months, but it would be dangerous to assume that another region with similar rainfall at this time would produce like yields even under similar soil and cultural conditions. Other environmental factors might be very different and materially affect the amount of moisture available from a given rainfall. The rainfall is only one factor, and others such as temperature, wind velocity and solar radiation might have as much to do with the quantity of water that the plants get as the number of inches of rain that reaches the soil.

There are many special problems that need careful study from the ecological and physiological point of view. The study of the various factors influencing fruiting, the parts played by each and the effects on the internal make-up of the plant is a type of research that is giving very important results. The work of Garner and Allard on the effects of length of day on fruiting; the nutrition studies of Kraus and Kraybill, Work, and others on vegetation and reproduction, and the studies of various workers on the effects of temperature and other factors on the same, are illustrations of this type of work. While very important contributions have resulted from studies of the type mentioned, we are just beginning to appreciate the importance of this field and have touched only the edges of it. The principles already worked out have very important applications to the problem of fruit and seed production. We are learning how to control seed and fruit production to some extent through control of some of the environmental factors This is very important information for the seed grower and the plant breeder. The knowledge of the factors affecting seed production will enable the vegetable grower to reduce losses from premature flower development of certain biennials as celery and cabbage.

In studies of the effects of light on plant growth most attention has been given to quantity of light and the duration of exposure. Might not the quality of light be just as important? Recent experiments with animals indicate that the quality of light is very important. These experiments show that sunlight passing through ordinary window glass is not effective in preventing or overcoming leg weakness and similar troubles. Since it is known that glass does not permit the passage of some of the short wave lengths it seems entirely possible that plants grown in greenhouses may be different from those grown in the open. Might not this vitiate some of our experimental results secured in the greenhouse? Studies on this problem are now under way at the Boyce Thompson Institute for Plant Research.

Miscellaneous Cultural Problems: There are many cultural problems on which some research has been done, but much more is needed. Among those we might mention intertillage, transplanting, hardening, and pruning. In fact, we might assume that nothing is settled.

Some of the most universally accepted practices and especially the advantages claimed for them, have not proven out when actually subjected to careful study. This is true of the advantages claimed for transplanting, for cultivation and for pruning tomatoes. The usefulness of these practices may often be traced to factors other than those generally emphasized. Much more study is needed to determine the actual effects of the practices mentioned on all of our vegetable crops and under a great range of conditions, before we can arrive at any definite conclusions. Then we need to go much further and determine how the treatments affect structure, chemical composition and function of the plants.

Storage Problems: Relatively little study has been given to the problems of storage of vegetables. There is need for thorough studies of the whole field. This should include a study of varieties and strains with reference to storage; the effects of stage of maturity and methods of handling on keeping; the effects of temperature, humidity and other factors on the keeping quality of various products. It is especially important to know the critical temperatures, and the optimum temperature and humidity of all important vegetables and fruits. Considerable has been done on apples and potatoes, but relatively little on the other fruits and vegetables. We ought to determine the changes which take place in the products during storage and the influence of the various environmental factors on these changes. This calls for very careful physical and chemical studies of all of our products.

Economic Problems: The problems in this field are as important as are those in any other, but they are likely to be considered as belonging in the field of economics. Horticultural knowledge is, however, very important in most of them. The studies needed include cost of production of the important vegetables, and studies on the whole field of marketing from harvesting through grading, packing, transporting, storing and selling, including costs. In most of these a knowledge of the products including the varieties is important. The problems of marketing of fruits and vegetables are more complicated than those connected with marketing wheat, corn and other standard farm products.

It is to be hoped that some of the funds made available through the Purnell Act will be devoted to some very thorough studies of the problems in fruit and vegetable marketing. Perhaps it would not be out of place for the horticultural workers to suggest special investigations or even to ask for funds to make some of the studies themselves. Unless those interested in horticulture do bring the problems to the attention of men doing the research in marketing, the funds probably will be used for studies of marketing other products.

Choice of Problems and Methods of Attack

Since it is impracticable to work on all problems at once, some selection is necessary. How should this selection be made? After we have found out what the problems are, I believe we should make an

analysis of the whole field to determine what type of work is likely to be of most value in solving practical problems and in extending knowledge. In making this analysis we might catalog the problems needing investigation under various categories. For example, there are some that are more or less peculiar to a particular group, as market gardeners, growers of muck crops, growers of canning crops, or to those producing some special crop, as cabbage or potatoes on general farms. It is obvious that some of the problems confronting one of these groups are very different from those confronting other groups. The market gardener is perplexed to maintain production under conditions of a decreased manure supply. On high-priced land, he cannot afford to give up part of the growing season to the production of a green-manure crop. This is no problem to the man who is growing 1 or 2 crops in connection with general farming, nor is it important to the growers of muck crops. On the other hand, there are problems that are more or less general.

In shaping our research program, it seems to me desirable to include some of the problems that are of interest to all groups of growers and then to round it out with the most important of the special ones. Of course, we should take into consideration the requirements in time, facilities, equipment and funds in taking up any problem. Obviously it would be a mistake to undertake work requiring more time, facilities and funds than we have available, but that is no excuse for not doing any research. We can do something worth while with any resources we have.

It is important to consider the problems from the point of view of subject matter that would be involved in an intelligent attack upon them. Some might require only a knowledge of the industry and plat technique; others a thorough knowledge of genetics, of taxonomy, of physiology, of histology or of chemistry. Of course we should attempt to solve only the problems which call for the mental equipment we possess. For example, it would be a waste of time and money for me to attempt to solve a problem calling for an intimate knowledge of genetics. I believe we should bear in mind, however, that solution of problems in vegetable growing and handling calls for knowledge of all the fields mentioned and some others. While it is too much to expect that any one individual can be well trained in many of these, it would be well for a department to have men trained in the several fields. It is a mistake, from the research point of view, for all of the men to have their special training in the same field of science. All should know vegetables and should have some training in several of the underlying branches of science, but beyond this it is desirable to specialize. One man might specialize in taxonomy, another in physiology, another in histology and still another in chemistry. From the point of view of solving specific vegetable problems, there is some danger in this specialization. A genetecist, for example, using the principles of genetics in improving beans is liable to become so interested in the inheritance of color or of some other character that he forgets about improving the beans. The physiologist, the chemist,

and others, are just as likely to go off on a tangent and forget what they started out to prove. I do not mean to say that these special studies should not be made. They should; but when we start out to solve a certain problem we ought not to get so interested in some particular aspect of it that we lose sight of the original one. Our duty, as horticultural workers, it seems to me, is to use the tools of the other fields to aid us in the solution of our problems and to advance our own field.

It is of some importance in making up a research program to consider whether or not the studies are likely to produce results. It is often worth while to include, along with the long-time studies, some which will be fairly certain to give results in a short time. A program made up entirely of studies requiring several years to give any results is likely to be disappointing, both to the investigator and to others concerned, especially to the director.

The experimental methods that should be employed depend to a considerable extent upon the nature of the problem. Some problems can be satisfactorily solved by conducting carefully planned field plat work. Others might require careful experiments under controlled conditions, in addition to field studies. Some need the most careful work in the laboratory to determine the internal changes brought about by the external treatments. In many types of problems, it is desirable to use all of the methods mentioned, especially if we want to know the fundamental explanation for the responses. In work on nutrition, for example, we might solve the problem to the satisfaction of the practical grower merely by conducting relatively simple field experiments, but we need thorough studies under controlled conditions to determine the parts played by the various factors. Along with this we need careful laboratory studies to determine the internal conditions associated with the observed behavior of the plants.

Some believe that we might eliminate a large part of the field experimental work and substitute for it the more carefully controlled experiments in the greenhouse. With some problems studies in the greenhouse might be all that is necessary, but with most of them the field studies are essential. As I have already intimated we have no way of knowing that plants will respond to a given treatment under field conditions in the same way they do under artificial conditions in the greenhouse. Experiments conducted in the greenhouse, therefore, must be repeated in the field before the results can be applied. Would it not be better to do the field work first and follow it with greenhouse and laboratory studies? The main value of such studies, it seems to me, is in explaining the results in the field and in helping us to interpret the responses of the plants in terms of the principles involved. This idea was well expressed by Chandler when he said: "It is probable that more often than otherwise when a discovery is made that explains in a fundamental way some response of the tree we shall look, not forward to its application, but backward to find it already in practice, placed there by the results of experience; of field experiments; and of studies of the more superficial responses that the

more fundamental study explains." This is practically as true of studies made with vegetable plants as with fruit trees. I do not believe that we can dispense with field experiments and I see no reason for doing so. With many types of problems, field experiments are the only kind that will give us results that are applicable to field conditions, and if they are properly planned and carried out they will give us information of a fundamental nature, as well as the solution of practical problems. What is needed is more and better field experiments and a more critical study of the plants themselves under the experimental treatments. If we know the variations in the soils of our experimental areas and have sufficient replications, I do not believe that we will have any more than the usual difficulty in interpreting results; no more difficulty, in fact, than we have in interpreting results of research carried on under so-called controlled conditions. With most problems we cannot substitute experiments in the greenhouse and analyses in the laboratory for field experiments, but it is very desirable with many of them to supplement the field work with the greenhouse and laboratory studies.

In conclusion I want to say that I am interested in research, whether or not it has any application to a particular practical problem, for any knowledge, however gained, is worth while, and is very likely to aid in the solution of problems in the future. I am also interested in what we call fundamental research, but I believe that it can be just as fundamental when carried on with apples or cabbage as with Spirogyra or Nitella. It can be just as fundamental when directed toward the solution of some practical problem as when the aim is merely to establish some scientific principle. Both might be accomplished on the same problem if well planned and well conducted.

Observations on Physiological Reasons for Productiveness in Seed Potatoes

By C. L. FITCH, *Iowa State College, Ames, Iowa.*

TO MOST people the Irish potato is a sort of mystery. I like to call it "The Mystic Spud;"—less of mystery and much more of understanding of the laws of productiveness in the potato would be for the general good and for the general profit.

The purpose of this paper is to put before this national group of scientists the needs of the potato industry in the United States for accurate quantitative statements of the influences that make for productiveness in seed potatoes. The soil temperatures and the factors of fertility,—in other words, the physiological or nutritional elements that give the seed potato producing power or the lack of it, need statement in figures. There is need for a lifetime of work to secure these figures.

The laws of productiveness that are well understood by the specialist are difficult to transmit to the understanding of the average grower and quite as difficult to place before the crowded attention of the average college student. Quantitative statements would make much easier the task of instruction in class room and in the field.

In the past 6 years we have grown quite complicated little studies of potatoes with about 700 farmers. Upon about half of these plots we have taken data with such accuracy as has been practicable in such volume of extension work. This year we had 136 of these studies in 44 counties and I have taken the figures myself on about 60 of them. The plan has been quite a uniform one for the 6 years. We supply 16 peck lots of the best certified seed from some of the best northern growers,—about 7 lots of Ohios, 7 of Cobblers, and 2 of Rurals. In the neighborhood of the study or demonstration we secure local lots of these same varieties that have been 1, 2 or 3 years, or longer, in Iowa. Thus, at harvest time, we have quite a study of the factors that make for or against producing power in the seed.

In addition to these seed studies on farms, we have had for 3 years 2 mother or control plots, and in them by cooperation with the Minnesota Seed Certification Board which has furnished us the samples, we test the relative productiveness of seed from all farms in Minnesota growing certified seed Ohios, Cobblers and Rurals, from which samples have been available. We have had seed from as high as 150 farms; in 1925 from 100 farms. Each sample is planted in 5 places in each of 2 plots, some 200 miles apart. In 1925 we had 1,000 numbered stakes, 1,000 weighings, 1,000 records of stand, and 1,000 ratings of the relative vigor and health of the vines. Last year and this we have lost no single stake or record.

Then in Clay county, Minnesota, with the Commercial Club of Moorhead, I have had this year 4 plots for the comparative testing of seed from different Clay county farms, by the tuber unit method, the object being, on our side, seed improvement at the source, and on the side of the Commercial Club of Moorhead, the encouragement of trade in seed potatoes from Clay county and from Moorhead.

With these 3 sorts of plots, this work has been like a great laboratory, not alone for demonstration, which is the primary purpose, but also incidentally for the development of the principles of productiveness in seed potatoes. The evidence is quite sufficient for the specialist, but not for record and transmission to farmer and student. Therefore, I come as an extension man to you as experiment station men, with my facts, suggesting that some or many of you subject these facts to more exact trial and secure the figures that will enable you and me to express these facts in more exact, impersonal and more universally convincing terms.

I call first to your attention the great physiological fact, that we grow most of our potatoes in the North and that growers in the warmer regions in the South must draw constantly upon the North for vigor in seed. Nowhere in the world is there such a trade in seed potatoes as in the United States. Nowhere else under one govern-

ment with developed transportation and a prosperous agriculture, is there the opportunity to ship carloads of seed potatoes from the cool North to the South where they could not be maintained. Great Britain has a little such trade from Scotland to the south of England and the great seed houses of England have a little trade in seed potatoes to the British colonies in warmer regions. There may be some such trade in Chili and Argentine. This trade, however, is many times greater in the United States than anywhere else in the world.

Seed Potato Principles Needing Quantitative Statement

We find that seed potatoes of early Ohio should come from at least as far north as Moorhead, Minnesota. Cobblers should come from a similar latitude. Rural seed may be had in full vigor from at least 100 miles further south. We get no better Rural seed than that from Barron county, Wisconsin, which county is situated a little to the north of the latitude of Minneapolis.

The nature of the soils from which seed potatoes come, is of great importance to us. Our experience with seed from very sandy lands just north of Minneapolis in the Red River valley itself, in the neighborhood of Wadena, Minnesota, and in the near corner of North Dakota and elsewhere, leads us to the conclusion that very light soils tend to produce seed potatoes which will mature too quickly and yield much less than they should. In our opinion after numerous trials, the so-called Six Weeks potato is nothing more or less than Early Ohio produced for a number of years on thin sandy land. We have had considerable experience with Ohios and Rurals from such land in different seasons and from different degrees of fertility and different sorts of rotation, manuring and fertilization, and we are led to the belief that potatoes can be maintained in *fine health*, but not in high-productiveness on sandy land with light fertility; and that with good rotation, good green manuring and the addition of chemical and natural manures, such light lands can produce seed potatoes which will yield with the same varieties from stronger or heavier soils. Nevertheless, the trade is entirely correct in wanting its seed potatoes on general from soils of considerable natural weight and natural fertility.

We are led also to the conclusion that one adverse season in the North does not greatly and perhaps not perceptibly reduce the yielding power of a stock of seed potatoes which has had superior nutrition for several years previous to the adverse season.

It seems to me that all these principles can be worked out quantitatively by large scale pot experiments such as those performed at the Colorado station.* Somewhat similar pot studies have been made by Dr. L. R. Jones at Madison, Wisconsin. Potatoes could be grown under controlled soil temperatures for several propagations and then their productiveness tried as compared with seed produced under different temperatures. Similarly, seed potatoes could be

*Fitch, C. L., 1915. Studies of Health in Potatoes, Bull. Colo. Exp. Sta. No. 216.

grown in different textures of soil and different degrees of fertility and then compared as to their producing power with seed produced for a like number of years in different soils and with different fertility.

The equipment for such quantitative experiments would need to be large and would cost some thousands of dollars or at least many hundreds of dollars. The work can best be done in the greenhouse in the winter in the arid region where sunshine will be available, where temperatures need not go too high, and where cold water will be available for the control of the temperatures of the pots. The work, however, where the winter lacks sunshine and the summers are hot, could be done in the greenhouse in the spring if the whole apparatus were moved outdoors for the last few weeks of the growing period; or the work might be done in any main crop potato region outdoors in pots under controlled soil temperature.

In any case, the field tests of temperatures, the field trials of seed produced under control, and the emergencies and new ideas that would arise as the experiments progressed, would make this undertaking one of many years. It would be worth all the time it might demand.

THE EFFECT OF VARIOUS SEASONS IN SEED CONSUMING REGIONS

The temperatures which any lot of seed potatoes happens to strike when it is brought from the north to be used in the cornbelt or in the South, have a great deal to do with whether that seed may be used more than once or not, as well as with how large a crop is secured from it the first year. If the first season, for instance, that a lot of Ohios strike when it is brought to Iowa is very hot, not alone may it produce a very poor crop that year, but it may be rendered by that season entirely unfit for use anywhere the next. Usually, however, a moderately adverse season will leave a stock of seed Ohios enough vigor so that, along with some increase in fertility in its new home, it will produce as large a crop the second year as new seed from the North would produce. However, seed Ohios seldom if ever hold their own to this extent for the third propagation in Iowa.

For lack of the understanding of this principle, the growers of Iowa have lost this year not less than 8 million dollars in crops. The seasons of 1922, 1923, and 1924, as potato growers know to their sorrow, were all too favorable to the production of large yields. These seasons also tended to the maintenance of seed Ohios in a reasonable degree of vigor so far as such vigor has been apparent to the ordinary grower. At the same time our experience shows very clearly that such seed, even though keeping up an average yield, was losing its power to produce if an adverse season came. In 1925 such a season and the use of such seed occasioned a loss in yield of several million bushels of potatoes which might have been secured had new northern seed been used.

Very similarly we have in Iowa a few growers who give their potatoes unusually fine conditions as to soil and fertility and the storage of seed. They seem to be able to maintain vigor in Iowa of their seed

stocks, but the moment they take such seed potatoes to soils with tougher or lighter subsoils and less fertility, they go to pieces and produce ruinously low yields.

A series of hot seasons quickly ruins the producing power of any lot of seed forever with us.

Irish Cobbler seed potatoes run out more quickly with us than Early Ohio and much more quickly than Rural seed. I suggest that the reason may be found to be that Cobblers mature a little later than do Ohios and so finish in midsummer heat, while Rurals have so much longer a season that they bridge the summer time while young with comparative vigor and produce their tubers in the cool of the fall. I suggest also that the temperature of the tuber bed and of the roots may be found to be the chief factor in maintaining vigor or in the loss of it. We need to get Cobbler seed from the North every year. The best Cobbler seed seems to come from strong clay lands such as those of Kittson county, Minnesota, or those about Duluth. Similar conditions are found here and there in the Red River Valley and where found seed from as far south as the vicinity of Moorhead seems to produce just as well as the Cobblers from farther north, although the appearance is seldom as good. In pot experiments the scientist may find that the need for Cobblers to come from stronger soils is that such soils maintain full nutrition until maturity better than lighter ones.

Rural seed potatoes we need to get from strong lands. The best practice for our commercial grower of Rurals seems to be to secure each year from the North about one bushel of Rural seed for each acre he will plant the second year with seed grown from them. It seems wise to plant the northern seed for seed production a little bit later than the Rural crop to be sold in August and September for consumption. In years like 1921, of prolonged summer heat, early planted Rurals were as badly crippled in producing power for 1922 as were early varieties like the Ohio and Cobbler. On the other hand, by late planting, many home growers of Rurals as far south as the Missouri line and beyond, have been able to maintain this variety in full productiveness for 25 years and there seems to be no reason why they should not maintain them indefinitely.

The farmer commonly thinks that rain is the first requisite for a potato crop. We do not find it so. If the subsoils be reasonably deep and if they have not been dried out by alfalfa roots or grass roots, we find that we often get nearly our maximum crops of potatoes in seasons of comparatively little moisture, provided only that they be cool. The season of 1922 was such an one. Of course, it usually is true that the coolness and the moisture come together, then often an excess of moisture does much harm.

We get our best crops on lands which have been in bluegrass or clover or in a thick stand of alfalfa, so that they have had their physical condition made good to a great depth; but we get these best crops by putting between the meadow crop and the potato crop, a cultivated one like corn or soybeans so that we have better subsoil moisture conditions and so that there is time for the roots of the meadow crops to crumble.

Specific Instances of Seed Potatoes of Superior Producing Power

I will give you the conditions under which the best Early Ohio seed potatoes of our knowledge have been produced. Probably there is no record in this country held by any grower of seed potatoes which equals that held for Early Ohio seed by Albert Peterson of Crescent Flats, Rhinelander, Wisconsin. In our farmer plots, Mr. Peterson's seed potatoes have been best three times and second best once out of the five years we had them in such plots. We have not yet figured the yields from these potatoes for this year but it looks as if his potatoes would again be best. In our Clear Lake control plots, they outyielded Ohios from all the farms growing certified Ohios in the state of Minnesota, some 50 of which we had under test, and the yields from Mr. Peterson's seed in this adverse year were just under 400 bushels per acre of U. S. No. 1 size and quality.

I have been to Mr. Peterson's farm and have kept in constant communication with him, ever since we discovered the excellence of his potatoes in 1921. He has a seed plot in which, by the tuber unit method, he maintains his own seed stock. He has used specially fertile land for this seed bed and has used 1,000 pounds of 2-8-5 fertilizer to the acre in addition to the natural fertility. The roguing from his seed plots has been very slight indeed. The health condition of his potatoes is very high. In his fields he also has maintained high fertility. His soil naturally carried a heavy stand of timber. It is a sandy clay loam, quite deep but with gravel streaks in beds beneath which give perfect drainage. He is located plenty far enough north so that summer temperatures seldom are adverse.

Mr. Peterson has profited greatly by the reputation which we have made for him. He recently went home to Denmark on the profits of 10 acres of potatoes. For several years he has not had to take less than $1.00 per bushel at his railway station for any of his Ohio seed. He shows some tendency, however, of resting on his oars and using a little less care in his seed plot and in the amount of fertility which he employs there and in his fields. For his sake and for the sake of the continuing example which he affords to all seed growers, we are urging him to maintain his standards high.

The second best grower of Early Ohio seed potatoes which we have found is Paul Tungseth of Hawley, Minnesota. One year his seed was better than all others, and several other years it was second best. The reason for the excellence of the Tungseth Ohios seems to be high fertility and mellow soil. He is in a coulee or valley where a great deal of black humus has been added to a deep, sandy loam. There are other lots of seed produced on similar soil in the immediate neighborhood which have very fine records with us, whereas, within a few miles the higher, lighter, less fertile, sandy loams produced some of the worst seed Ohios we have ever had on test.

The Excellence of Seed Potatoes Grown on Peat Land

In the central and north central portions of Iowa there are considerable areas of peat. Most of these areas have been drained and

many of them are used for potatoes. We have had a number of demonstrations on peat soils and have discovered that these lands are able to maintain seed potatoes indefinitely, for their own use, and that peat grown seed, if not too long in Iowa, is good for the neighboring uplands. On the peat we even are able to grow varieties which ordinarily must be produced on mellow lands in the far North, for example, Russet Burbank and Green Mountain, to a considerable degree of satisfaction and profit. The Green Mountain perhaps may be our best potato for the peat lands. It has no other place in Iowa agriculture.

At Hollandale near Albert Lea in southern Minnesota, 17,000 acres of peat lands recently have been drained and are being brought under production for trucking. This year we planted on 136 farms in Iowa, Cobblers which had been 1 year on the peat at Hollandale, and also Cobblers which had been there for 2 years. We have not yet summarized these figures, but it is apparent that these Cobblers have produced as large a crop and of as fine quality as the very best strains of Cobblers produced in the far North. It may be that we shall find the peat lands of Iowa and of southern Minnesota invaluable for the production of seed potatoes.

I suggest that the excellence of peat grown seed potatoes may be due to the coolness of the tuber and root bed due to the superior insulating value of the dry peat on the surface, and the superior moisture and cool temperature of the peat below, as well as to the high nitrogen content. The Hollandale potato lands also are supplied with a large amount of the other elements of fertility by the liberal use of 0-12-6 fertilizer.

All of these facts are highly suggestive to the scientist who would put yielding power of seed potatoes into exact quantitative terms.

Early Potatoes Kill Nearby Late Potatoes

In our 700 seed studies with farmers in the past 6 years and in our control plots for the last 3 years, we have planted each year and everywhere a few lots of late potatoes, mostly Rurals but including also some Green Mountain and some McCormick and other potatoes of the Peachblow family. We have failed almost universally to get a good crop from the late varieties when planted with the early sorts. When they have been mixed among the earliest they have produced particularly poorly, as they have when placed in rows running east and west and immediately to the north of early potatoes, so that southerly winds come across the early potatoes onto the late ones.

Our purpose in bringing the McCormick to Iowa from the vicinity of Washington, Baltimore, Philadelphia and Wilmington, where this late variety is such a large factor in the seed potato supply, is to try to make the variety similarly useful to the farmers and market gardeners of Iowa. A number of instances have come to our attention each year where farmers planting potatoes of this family by themselves, in many cases in acreages up to 15 or 20, have made a success of the undertaking. We have one farmer who has grown Bonanzas con-

tinuously with success by late planting and using his own seed for nearly 40 years.

In our plots the late potatoes have been almost always nearly complete failures, whereas, often nearby these farmer fields of the late variety by itself, have been substantial successes.

There can be no other explanation than that the late potatoes have been caused to die earlier than they otherwise would, by the mere presence of the early sorts. Doubtless the leaf hopper has been the means of carrying a virus from the early potatoes to the late ones. This conclusion is entirely in harmony with the recent studies by Johnson,† in which he finds that innoculations from seedlings do not seem to transmit viruses and that Rurals apparently contain less poison of some kinds (for the tobacco plant) than do other varieties of potatoes. Rurals, it will be noticed, are our *latest* common variety.

Some observations in this connection may or may not be significant. They appear to be so:

(1). On one of the high mesas above Carbondale, Colorado, I have seen Bliss Triumph potatoes which produced an enormous crop and appeared to be, for that season, a true late variety. Similarly, in the vicinity of Alliance, Nebraska, a great many fields of Triumphs did not ripen at all in 1917. They were simply stopped by the frost that came late in September.

(2). In the greenhouse at Fort Collins, Colorado, in the winter of 1910-11 we had a vine of the Pearl Bastard which kept on growing all winter and spring. It is a matter of common knowledge among horticulturists that whereas early varieties of tomatoes often finish in mid-summer, sometimes, as in California, tomato vines grow indefinitely.

(3). It may be that in these things we are skirting the edges of something pretty basic. Perhaps even the reasons why some varieties are early and some are late. Be that as it may, the effect on productiveness of transmitted viruses and of the control of the leaf hopper through Bordeaux spraying should be studied. The leaf hopper is often exceedingly serious in our seed producing regions. It may be that potatoes should not be certified unless they have been frequently and well sprayed with Bordeaux mixture.

(4). This killing of late potatoes by early varieties is in harmony with the gain secured by the control of leaf hoppers in fields of one variety. Perhaps it may be found that the picking off of the older leaves may increase the potato crop from vines under test. This whole matter of the damage which the nearby presence of early potatoes does to late varieties, could readily be put to test by planting in a field of late potatoes here and there in definite blocks from one to many early potato plants and studying the zone, or distance, differences in yields of the late potatoes appear around the early plant or plants.

Conclusion

Anyone who has seen the physiological elements in productiveness of seed potatoes cannot but feel sure that the entomologists have

†Johnson, James, 1925, Research Bull. No. 78, Wisc. Agr. Exp. Sta.

greatly over-emphasized the importance of the leaf hopper in the early death or in the long life of varieties of potatoes. They have underestimated the physiological factors. For instance, one entomologist‡ has told us that potatoes are affected by "hopperburn" in the following order: Early Ohio, Irish Cobbler, Green Mountain, and Rural. This is the order in which these varieties mature anyway

We as horticulturists are deeply indebted, however, to the entomologists for showing us that the leaf hopper is the chief carrier of early death of leaves and plants.

To the pathologists we are indebted for the quarantine idea and the certification idea as applied to seed potatoes. However, it seems to me that in this paper alone, there is enough evidence to prove that certification of Irish seed potatoes cannot well be carried on without taking full cognizance of horticultural factors in productiveness of seed. I would far rather have seed potatoes, for instance, which might be disqualified for carrying a considerable percentage of rhizoctonia but which had come from a high producing stock of seed and from a fertile northern farm, than to have seed certified to be entirely or almost entirely free of disease and yet known to have come from a stock maintained for altogether too many years on thin sandy land or on a farm too far south for efficient physiology and nutrition.

The Value of Check Plots in a Fertilizer Experiment with Cabbage and Tomatoes

By W. D. Mack, *Pennsylvania State College, State College, Pa.*

A PROJECT on the fertilizer requirements of certain truck crops in a rotation has been in progress at the Pennsylvania Agricultural Experiment Station since 1917. The crops which have been grown are early cabbage, early potatoes, tomatoes, and a cereal followed by sod, in a 4 year rotation in the order named. The cabbage has now completed the ninth year, the potatoes the eighth, and the tomatoes the seventh.

The detailed plan of this experiment may be found in the report of this Society for 1917 under the title "The Planning of an Experiment for the Fertilization of Vegetables." It is sufficient for the purposes of this discussion to state that the experiment comprises over 6 acres of land, divided into 4 equal sections. The above rotation is followed on each section, and each of the 4 crops is grown annually on one or another of the sections. The sections are divided into 6 tiers of 17 plots each. The size of the individual plots is one-hundreth of an acre.

The first, fifth, ninth, thirteenth and seventeenth plots of each tier are checks. There are thus 30 check plots in each of the 4 sections.

‡Fenton, F. A., and Hartzell, Albert, 1923. Research Bull. No. 78, Iowa Agr. Exp. Sta.

These were unfertilized during the first 6 years of the experiment, but since that time they have received a uniform application of fertilizer equivalent to a half-ton of 4–10–0 per acre for each of the truck crops. This change was made necessary because the yield of cabbage on a number of these plots had fallen to zero.

The soil of the experiment is Hagerstown clay loam. It was producing uniformly good field crops before being used for the present project. Records were taken on the weight of grass and clover and on the uniformity of this crop on the plots immediately before the experiment was begun. These records indicate a very fair uniformity of the soil, at least for hay production. The entire area is fairly level, as the maximum difference in elevation between the highest and lowest points is not over 10 feet.

The checks, however, have shown a surprising lack of uniformity in yield of truck crops. This variability was first commented upon and investigated by Pelton, who reported the results of his studies in the Proceedings of the American Society for Horticultural Science for 1921, under the title, "Possible Cause for Variation in Yield of Check Plots in a Fertilizer Experiment with Vegetables."

Last year when the results of the first 8 years' work with early cabbage were being summarized, it was observed that correction of plot yields by the use of checks sometimes resulted in large changes from the observed yield. When several plots under similar treatment were corrected, the change was sometimes away from the average of the similar plots, rather than toward it, as it reasonably should have been.

A study was, therefore, undertaken on the results of corrections to the yields of the checks. Fortunately for the purpose of the investigation there are 17 standard complete fertilizer plots scattered throughout each section, all of which are fertilized alike. They receive an application of fertilizer equivalent to 1000 pounds of a 6–10–8 mixture. The study, therefore, was concerned mostly with these plots, and the effect on their variability brought about by correction to the values of the checks.

It was considered that if correction were made for any factor causing variability, it is reasonable that the coefficient of variability of a series of plots should be reduced by the process. The yields of these standard fertilizer plots were, therefore, corrected, and the coefficients of variability before and after correction were calculated. This was done for the yields of each year separately.

The corrections were made by this formula: Corrected yield of plot $= \frac{\text{Observed yield of plot x average of checks}}{\text{Assumed yield of plot if treated as check}}$. The assumed yield in one series of corrections was taken as the average of the 2 checks between which the given plot was located; in another series the assumed yield of a given plot was found by distributing the difference between the 2 checks evenly among the 3 plots intervening. The latter method assumes that the nearer of the 2 check plots is a better indicator of the yield of a given plot than another which is one

plot farther removed. Where the given plot is midway between the 2 checks, the assumed yield is, of course, the same in both cases.

The coefficient of variability of the 17 standard fertilizer plots was increased by the corrections in 5 years out of 8, when the assumed yield was taken as the average of the nearest 2 checks. When the weighted average was taken as the assumed yield of a given plot, the coefficient of variability was increased in 6 years out of 8. Some of the increases were quite large, since several of the coefficients were more than 3 times as great after correction as before. In the cases where correction resulted in a decrease in variability this reduction was correspondingly quite small.

It is worthy of note, however, that in one of the cases in which the coefficient of variability was reduced, the corrections were made to yields of the same check plots taken in the previous rotation. This was done because in 1921, the particular year in question, the yield of several of these checks was zero. Therefore, the yields of the same checks from the previous rotation were used in this year, and likewise in 1922.

The above exception drew attention to the fact that the yields of the checks for 1917, in the previous rotation, were larger than the yields of the standard fertilizer plots in 1921. The correction, therefore, has been made to a series of plots which were higher in yield than the plots which were being corrected. With this in mind, the checks near the standard fertilizer plots, 18 in number, were considered as the treated plots, and corrections were made to the yields of the standard fertilizer plots nearest them. The variability of the corrected and uncorrected checks was then studied.

The checks, after being corrected by this method, had a smaller coefficient of variability than before in 6 years out of 8. In the other 2 years they were slightly more variable after correction. In no case was there a very large change in the coefficient of variability.

There is a fact that might be emphasized at this point. This is that in 1923 and in 1924, when the check plots were fertilized as previously described, the use of these checks for the correction of the standard fertilizer plot yields resulted in just as big an increase of the coefficient of variability as did that of unfertilized checks in other years.

The yields of tomatoes on the standard fertilizer plots were next studied in similar manner. Data for 7 years were available for consideration. Correction of the standard fertilizer plots resulted in a larger coefficient of variability in 3 years, and in a smaller one in the other 4 years. One of the increases took place in 1924, when the checks were fertilized; the other two occurred in 1921 and 1922, when they were unfertilized.

The variability of the checks when corrected to the nearest standard fertilizer plots was greater than before correction in 4 years and less in 3. Two of the increases resulted in years when the checks were unfertilized, and 2 when they were fertilized.

The foregoing results lead to the conclusion that the soil variations

in this particular area are not at all consecutive from plot to plot, nor is one plot an indicator of the yielding capacity of the plots near it.

In order to test out the above conclusion the individual plant records were consulted. In 1924 the yields of tomatoes were recorded for each plant, and in 1925 the cabbage yields were taken in the same manner. On tier 6 of each section the three plots between any two checks have been fertilized alike. The yields of plants in one row were compared by "Student's" method to those in the next. These in turn were compared with the plants in the third row, and so on. If soil variations were consecutive or graded, significant differences should have been found by this comparison, when one check plot had a considerably larger or smaller yield than the next one.

No consistent differences, however, were found by this method of study. Significant differences between rows were found, but they were just as likely to be in one direction as the other.

Finally, all the yields of cabbage for the 8 years were corrected to the checks as previously described, using the weighted average of the nearest 2 checks in the formula given above. Studies of the differences between the various treatments were made throughout the experiment. The odds in favor of these differences being due to causes other than chance were found by "Student's" method, both for corrected and uncorrected yields. Ninety-one such comparisons were made. In 65 cases the odds were reduced by correction; in 6 cases, no change resulted; in the remaining 20, the odds were increased. In other words, the significance of the difference between any 2 treatments was lessened 3 times as often as not, when the yields were corrected to the value of nearby checks.

Conclusion

The conclusion to which one is obviously led is that, in the project under consideration, the checks might better have been omitted. This is true at least with regard to their value in correcting for the factor of soil variation. This was the case for unfertilized checks, checks with a medium fertilizer application, and for the heavily fertilized standard fertilizer plots when used as checks.

It is not likely, therefore, that the situation could be improved by fertilizing the checks heavily. The recommendation which seems safest is that in planning future plot experiments on the soil type question, the space which might be occupied by checks had better be used for replication of treatments to be compared. If any 2 treatments are to be studied, it is safer to locate them near each other in repeated comparisons. Errors caused by soil variability are likely to be diminished by this method more often than they will be by the use of checks.

Toxic Relation of Other Crops to Tomatoes*

By W. H. ALDERMAN and J. A. MIDDLETON, *University of Minnesota, St. Paul, Minn.*

IN "SCIENCE and Fruit Growing," page 293, Bedford and Pickering discussing a large number of experiments demonstrating a toxic effect of one crop on another report "In no case have negative results been obtained, either as to susceptibility of a plant to the influence of surface growth or to the deleterious effect of a plant when grown as a surface crop." This quotation is from a statement made after a long continued study of 18 or more crops grown under, or associated with, 21 surface or cover crops. One of the crops studied intensively, both as a cover crop and as a principal crop, was the tomato. The purpose of this brief paper is to show a small amount of distinctly negative evidence in an experiment with tomatoes grown under control conditions and extending over 2 years at the University of Minnesota.

In the fall and winter of 1922–23 and in the winter and spring of 1924, tomatoes were grown in the greenhouse in cubical wooden boxes 14 inches on a side. Fitted into the top of these boxes were galvanized iron trays 4 inches deep. The bottoms of these trays were perforated to allow moisture to soak through and were so constructed that a 4 inch opening was left in the center through which the tomato growing in the larger box extruded. The bottoms of the trays were covered with fine wire gauze, 100 meshes to the inch, which effectively prevented the growth of cover crop roots from penetrating into the soil of the larger boxes and coming into contact with the roots of the tomato. A series of 10 cover crops of various types was planted in the trays and a fair seedling growth established before these trays were superimposed over the soil in the boxes containing the tomato plants. The plants of the tomato, variety Manifold, were selected from a considerable number of seedlings to insure as uniform a group as possible. Three boxes were grown for each type of cover crop and the data presented are an average for the 3 except in a few instances where accident reduced the number in the series to 2. The soil used was carefully prepared to secure uniformity and would be characterized as a sandy loam of medium fertility. All water was applied to the cover crops in the trays so that the only moisture secured by the tomato came from seepage from the trays filled with cover crops. The checks were handled similarly to the others in every respect except that the superimposed trays were filled with soil, but did not contain growing plants. The following table indicates the total average height in inches and the yield in grams from each of the several series for 2 years. Since the yield of the plants is very erratic and may have been affected by student invasion at unguarded times, such data are probably of little value,

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although they show in 1923 that the check plants were the lowest yielders of all except buckwheat and in 1924 the check plot was intermediate, being exceeded in yield by 4 plots, while 5 gave yields lower than the check.

TOTAL GROWTH OF TOMATOES IN INCHES AND YIELD IN GRAMS FOR TWO YEARS

	Height in inches		Yield in grams	
Cover crop	1923	1924	1923	1924
Rape	91.0	32.7	2238	1372
Rye	90.5	34.7	2058	2170
Red Clover	86.7	38.0	2471	1642
Buckwheat	86.5	36.6	1516	1454
Vetch	86.0	40.0	2516	1652
Alfalfa	86.0	39.3	3058	2688
Peas	84.7	38.7	2173	2191
Soy beans	82.0	41.0	2791	1884
Check	78.0	35.3	1631	1831
Blue Grass	69.6	36.8	2387	1793

Since the tomatoes were pruned to a single stem and weekly growth measurements were taken of the height in inches, it is felt that the data here are both interesting and reliable. It will be noted that in 1923 the check plot made the poorest growth of all except that carrying a blue grass cover. In 1924 the check plot again made a poor growth, being exceeded by all other plots except the rye and rape series. Measurements were not continued over as long a period in 1924 as in the preceding year and consequently the total heights shown are somewhat less than those for the first year. It will also be observed that the blue grass was comparatively low each year, although it slightly exceeded the check plot in 1924. The growth made under the rye and rape cover crop was the best of all the series in 1923 and in 1924 these two sank to the lowest point. No explanation of this reversal in the two plots indicated is attempted.

The significant feature of these experiments lies in the fact that an attempt was made to duplicate the experiments of Bedford and Pickering under control conditions and that there was not the slightest indication of any deleterious effect of the surface crop on the crop grown beneath. Since the tomatoes received only water leached from the trays carrying the living cover crops, it would seem that there could be no escape from deleterious effects if soluble toxic materials were extruded from the roots of the cover crop. Since there was absolutely no indication of such toxic effect, it would indicate the desirability of carefully checking the work of the Woburn Station workers to learn if it is possible to reproduce the results secured by them on plants other than the tomato. The whole question of toxic reaction of one plant to another one grown in close association has long been a mooted question. The small amount of evidence herein reported opens to question one of the classical and outstanding experiments purporting to demonstrate the presence of active toxins which were presumably given off from the roots of actively growing plants and which affected adversely the vigor of other plants growing in close proximity.

Studies in Pruning and Training Tomatoes

By H. W. SCHNECK, *Cornell University, Ithaca, N. Y.*

ONE OF the problems that has been studied by many vegetable gardening college men during the last 10 years is the effect of pruning and training tomato plants upon different factors, such as earliness and yield. These studies, all of which have been made under outdoor field conditions, have indicated varying results, due probably to different conditions, and vegetable gardeners have different opinions as to the merits of the practice. One factor which some investigators have not considered and which has appeared extremely important to the writer in all pruning and training work with different plants, is the fact that in practice pruned plants are not given the same spacing as unpruned plants.

OBJECT OF EXPERIMENT

In order to get at some of the factors involved, an experiment was planned and conducted during the spring of 1925 in one of the Cornell University greenhouses. The plants were grown in large wooden boxes in order to have control of soil moisture conditions and to allow for an accurate study of root and top growth. The object of this experiment was to determine the effect of pruning tomato plants to a single stem upon yield of fruit, earliness, size of fruit, and vegetative growth of plant.

METHODS OF PRUNING AND TRAINING AND PLANT ARRANGEMENT

The plants were handled in 2 different ways, 1 set was allowed to grow naturally, and the other set was pruned to a single stem and this was tied to a stake. The side shoots were pinched off as soon as they began to form.

The boxes used for the plants were 14 inches square and 14 inches deep, and the inside of each box was coated with paraffin so as to make it water-tight. Ninety pounds of air-dried, screened greenhouse soil, was weighed into each box. It was found that by adding 18 per cent of this weight or 16.2 pounds of water to the soil, it provided the proper moisture content for good growth of tomato plants. The water content was brought up to a definite point at each watering throughout the period of growth by weighing the boxes with the soil. The plants were watered every 3 days during the first 10 weeks they were in the box and every 2 days during the last 6 weeks. The boxes were arranged so as to have the plants spaced approximately the same relatively as when grown in the field, or 3 by 3 feet for unpruned plants, and 3 feet by 18 inches for pruned plants.

The variety used was Bonny Best. Plants were grown from seed sown January 12, the seedlings were transplanted 2 weeks later and potted in 4 inch clay pots on February 25. They were shifted to the boxes when 9 to 10 inches high, when in bud, but without any flowers opened, on March 20. The same amount of water was given each

plant until April 14, when it was found that the unpruned plants required more water at each watering thereafter than the pruned plants; indicating a greater transpiration due probably to greater leaf surface on the unpruned plants.

Effect of Pruning on Yield

The results shown in Table I are based on one year's experiment with 14 plants in each treatment under greenhouse conditions. There were twice as many pruned plants per given area as unpruned plants which is approximately the proportion in field plantings.

TABLE I—Effect of Pruning Tomatoes on Yield

Treatment	Mature fruit per plant		Mature fruit per 100 square feet		Green fruit per plant	
	Number	Pounds	Number	Pounds	Number	Ounces
Pruned	14.8	3.1	328.2	68.9	9.2	20.4
Unprun'd	19.0	3.4	211.1	37.8	20.6	21.0

The number of mature fruits per plant produced by pruned plants as compared to unpruned plants is 22.3 per cent less and the weight is 8.8 per cent less, but the number is 55.5 per cent greater and the weight is 82.2 per cent greater when considered on the basis of unit of area occupied which is the principal basis of comparison on a commercial scale. From the time that fruits were first harvested until the conclusion of the experiment, was a period of 8 weeks and 5 days. Table I indicates that if the plants continued to mature fruits the total yield per plant would have been still greater for unpruned plants as compared to pruned plants. Barring disease, the longer the bearing season in any region, the greater will be the yield per plant of unpruned plants as compared to pruned plants. With the tomato the yield per plant is not as important from the commercial standpoint as the yield per given area.

Effect of Method of Pruning on Earliness

The total number of fruits per plant harvested up to each harvest time was greater on the unpruned plants than on the pruned plants to the end of the fourth week of harvesting, when the total number per plant harvested from pruned plants surpassed unpruned plants. The first fruits were harvested from unpruned plants on May 9, 5 days before any fruits matured on pruned plants. But the total yield in weight at the second harvest from unpruned plants which was the first harvest from pruned plants was less and continued to be less for each harvest during the first 4 weeks.

At the end of 4 weeks of harvesting the total yield that had been secured from unpruned plants was 5.7 fruits weighing 16.3 ounces per plant as compared to 6.2 fruits weighing 23.1 ounces from pruned plants. For the second period of 4 weeks 5 days of harvesting the yield in number of fruits and in weight from unpruned plants was greater than from pruned plants, unpruned plants producing an

average of 13.3 fruits weighing 37.5 ounces as compared to pruned plants 8.5 fruits weighing 26.5 ounces. Forty-six and six-tenths per cent of the total yield in weight secured from pruned plants was secured during the first 4 weeks, whereas 30.3 per cent of the total weight with unpruned plants was secured in that period of time. Not only was the total yield per unit area greater, but the early yield was also greater where vine growth was limited by pruning. The effect of pruning in increasing earliness was much more pronounced when considered on the unit of area basis than when considered on the plant basis.

Effect of Pruning on Size of Fruit

The average weight per fruit of marketable fruits produced on pruned plants was 3.4 ounces, while that on unpruned plants was 2.85 ounces. This is an increase in size of 19.3 per cent on pruned plants. This relationship in size was approximately the same for fruit harvested during the first 4 weeks as for fruit harvested the last 5 weeks, although the size was somewhat smaller the last 5 weeks for both treatments. Pruning decreased the total number of fruits per plant, but increased the size of fruits.

Effect of Method of Pruning on Vegetative Growth of Plant

The effect of pruning on vegetative top and root growth was studied in order to determine the reasons for the differences in fruit development, and the effect of fruitfulness on vegetative growth. The average total green weight of vegetative top growth of pruned plants was 29.1 ounces per plant. The weight of unpruned plants was 38.7 ounces. This seems somewhat small for unpruned plants due possibly to limited nutrients. The total green weight of root growth per plant at the close of the experiment was 29.8 grams for pruned plants and 30.5 grams for unpruned plants. Large top growth produced practically the same amount of root growth as smaller top growth, but more fruits were produced by large top growth.

Limiting top growth by pruning off side shoots did not limit root growth, but did limit fruit development. This is very different from the results secured in pruning cucumbers at Cornell University which were reported at these meetings a year ago where it was shown that heavy pruning greatly increased the amount of early fruit produced, sufficiently so to greatly reduce the root growth and vegetative top growth of the plant.

The tomato plant can be severely pruned. This allows closer planting which under the conditions of this experiment produced a large early yield, although the individual plant did not yield as heavily, but did produce larger fruits than plants which developed more vegetative growth.

With unpruned plants, 1 ounce of top growth produced a total including green fruits on plant at end of experiment of 1.02 fruits weighing 1.95 ounces and .79 gram root growth. With pruned plants

1 ounce top growth produced .82 fruits weighing 2.40 ounces and 1.02 grams root growth. This indicates a larger amount of fruit and of root growth per unit of top growth with pruned plants, but since more fruits develop per unit of top growth on the unpruned plants it would seem that they draw somewhat upon the plant food made in the leaves at the expense of root growth. Furthermore, more fruits develop early on unpruned plants, which accounts further for the proportionately smaller root growth per unit of top growth on unpruned plants.

With an annual plant such as the tomato, the effect of pruning on vegetative growth is not as important from the standpoint of food storage as it is with long-lived fruit trees, provided sufficient vegetative growth is allowed to produce a large root system and a large yield of the size and type of fruit desired. It seems that by pruning tomato plants to a single stem the plant is capable of producing a larger amount of root growth per unit of vine, and of supporting a larger weight of fruit per unit of vine. This experiment indicates that by pruning under greenhouse conditions, a more compact, upright growing plant is produced, thus allowing for closer planting and production of heavier vegetative growth as well as fruit per unit area than where plants are not pruned and trained

Steam Sterilization of Greenhouse Soil and its Effect upon the Root System of the Tomato

By ORA SMITH, *Iowa State College, Ames, Iowa.*

THESE investigations were carried on to determine just what alteration, if any, the root systems of plants undergo when the plants are grown in soil which has been subjected to steam sterilization.

Several investigators have noted the tops of plants grown in steam sterilized soil to have a greater amount of growth than the tops of plants grown in soil not so treated. It was assumed that there probably was some similar effect exerted upon the root systems of these plants. This investigation endeavors to determine if there are any changes and also their nature.

MATERIALS AND METHODS

Stokes superstandard strain of Bonny Best tomato was used throughout this experiment. The plants were grown in the greenhouse in wooden boxes 18 inches long, 18 inches wide and 10 inches deep. Unless otherwise specified, all soil used was ordinary composted blue grass sod that had grown on a fertile loam soil and was similar to that used in our greenhouse benches. All soil was sifted through a one-eighth inch mesh sieve. The soil was sterilized by the

inverted pan method for a period of 45 minutes with steam at 60 to 80 pounds pressure.

Two series were carried through the experiment. Series A consisted of 8 boxes, 4 made up as follows: Steamed soil was placed in the box until it was half full, this was compacted and the Briggs' (1) paraffin seal one-sixteenth inch thick was applied. The box was then filled with unsteamed or check soil and sealed with paraffin as before. Entrance of air and water was provided for by 2 glass tubes three-eighths inch in diameter penetrating each layer of soil. The arrangement of the soil layers in the remaining 4 boxes of this series was just the reverse, the check soil being placed in the bottom layer and the steamed soil in the top layer.

A hole was cut through the paraffin layer in the center of each box and 8 tomato seeds sown in each. Twenty-one days later the plants were thinned to 1 healthy seedling.

Series B differed from Series A in that the paraffin partition separated the box into 2 equal portions perpendicularly rather than transversely as in Series A. One side was filled with steamed soil and the other with check soil. The top surface of the soil was sealed over with paraffin and the entrance of water provided for as in Series A. In this series the seeds were so placed on the paraffin partition in the center of the box that as a result the roots of the same plant grew on both sides of the partition and thus into both kinds of soil. In both series equal amounts of water were given to each soil layer. Although this appears to be the only applicable method to use it introduces an error. In another experiment conducted by the writer (2) it was shown that steamed soil has a lower waterholding capacity than unsteamed soil, but that the steamed soil is more efficient in supplying the roots of plants with moisture. Therefore, the soils will not be treated alike if given equal amounts of water because of this variation.

The plants in Series A were washed out at the ages of 50, 52, 80 and 82 days and those of Series B at the ages of 47 and 78 days.

One side of the box was removed and the soil washed from the roots by a gentle stream of water. About half of the root systems were exposed and drawings made natural size. Measurements were made and the roots represented as nearly as possible as they were growing in the box. All of this extra work and precaution was taken because the details were brought out much clearer by this method than is possible by photographs of the actual roots.

Discussion

The drawings and photographs of the root systems of these plants show a very great difference in the size, extent and fineness of the root systems of plants grown in steamed and unsteamed soils. Those plants grown in steamed soil have larger roots, a greater number of roots and of a more fibrous character than those plants grown in unsteamed soil.

Soil concentration studies conducted by the writer indicate that steaming the soil increased the concentration of the soil solution

probably by making more plant nutrients available. It is suggested that this increased concentration of the soil solution is one factor causing the better development of the roots.

Studies by the writer (2) also suggest that changes in the texture, moisture content and the movement of water in the soil caused by steam sterilization, aid in producing a more fibrous and extensive root sy stem.

To obtain further evidence of the effect of steamed soil upon root growth, two lateral roots of approximately equal length were selected from each side of the paraffin layer in each of the boxes of Series B and the number of roots of the second, third and fourth orders were counted and recorded in the following table.

TABLE I—AVERAGE NUMBER OF TOMATO ROOTS OF SECOND, THIRD AND FOURTH ORDERS IN THE STEAMED AND UNSTEAMED LAYERS OF SOIL WITH PLANTS 47 AND 78 DAYS OLD

Series B

Treatment of soil	Plants 47 days old			Plants 78 days old		
	Order of roots			Order of root		
	Number Second	Number Third	Number Fourth	Number Second	Number Third	Number Fourth
Steamed.........	56.0	21.25	2.5	60.5	35.37	12.0
Unstemaed.......	39.12	10.1	1.0	43.5	21.12	3.12

In every case the number of roots of second, third and fourth orders growing in the steamed soil exceeded the number in the check soil. It is also shown that between the ages of 47 and 78 days that the increase in the number of roots is almost entirely in the third and fourth orders, few roots of the second order being produced during this period. As it is the smaller and finer roots and root hairs that furnish the absorbing surface for the plants, these figures indicate why the remainder of the plant or tops are generally of greater size and weight.

CONCLUSIONS

From the results of this investigation it appears that steam sterilization of greenhouse soil is a very good method of increasing the size, extent, fineness and number of absorbing roots of the tomato plant.

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Ripening of Tomatoes*

By J. T. ROSA, *University Farm, Davis, Calif.*

SHIPMENTS of tomatoes filled 27,351 cars in 1925. Most of these tomatoes come from the southern states and California, and are shipped for the most part as "green wraps"—fruit picked in the green-mature condition. The ripening of these fruits after arrival at destination is an important problem.

Our knowledge of the ripening process in tomatoes has been reviewed and extended by Duggar (1) and by Sando (2). Duggar found that the formation of the red pigment, lycopersicin, was inhibited by temperatures above 30°, and by lack of oxygen. Green fruit stored in nitrogen, hydrogen and carbon dioxide did not develop the red pigment, but in oxygen formation of the pigment was more rapid than in air. Sando found that oxygen supply was necessary not only for the development of pigment, but for the combustion of acids and the development of desirable flavor in artificially ripened fruits. Sando also investigated the chemical changes during growth and ripening of fruit of Globe, and found that increase in reducing sugar and decrease in total acidity were the outstanding changes in the ripening process. Possible criticisms of Sando's work are that he considered only one variety, as grown in Florida in the cooler part of the year, and that insufficient analyses were made of fruit passing from the green-mature to the full ripe condition.

The work of Denny (3) on coloration of citrus fruits with ethylene gas suggested that similar means might be employed for the coloration of green tomatoes. In connection with the storage and ripening experiments, it has become necessary to re-investigate certain of the ripening processes in tomatoes, and results somewhat at variance to those of Sando have been obtained.

In this work, 3 varieties have been used, Earliana, Stone and Globe. These varieties are quite distinct from each other, and are standard sorts for local production in the east and for shipping purposes; Globe being much used in the Gulf States and Earliana and Stone in California. The experiments were run during August, September and October on fruit grown at Davis, California, under irrigation. The chambers wherein the ethylene gas was used were of 430 litres capacity, and were by no means gas-tight, though by lining with building paper they were made reasonably so. These chambers as well as the check lots, were kept in a large basement where the temperature is quite constant. The average temperature prevailing during each experiment is given in the table, however. The ethylene gas used was obtained from the Fruit Growers Supply Co., of Los Angeles, in a compressed cylinder. The quantity required for the stated concentration was measured over water, and run into the chambers once each day. As there was some diffusion of gas from the chambers, the concentration therein was no doubt lower much of the

*Contribution No. 10, Division of Truck Crops, University of California.

time than that stated in the table. The chambers were also opened every day to prevent any oxygen deficiency. The fruit used for each experiment was picked on the same day, taken to the laboratory at once, and sorted to obtain fruits that were as uniformly as possible of the "green-mature" stage as judged by size, color and condition of the abscission zone. The selected fruits were then divided into 3 lots for storage under the different conditions. Sando has emphasized the difficulty of selecting green fruit of uniform maturity on the basis of size alone. The fruits used in these experiments, while perhaps not quite so uniform in maturity as could have been secured by tagging the flowers at blossoming time, still compare favorably with the commercially picked and packed product. Table I gives the summarized results of 7 experiments.

There does not seem to be any significant difference in the effect of the 2 concentrations of ethylene used. The Earliana exposed to ethylene reached full color in 5 days less time than the checks; with Globe there was a gain of 8 days; with Stone there was a gain of 7 days, both at 20° C and 18° C. Coloration was noticeably retarded in the experiment at 18°, and at 16° coloration was much slower, both in air and in ethylene. The optimum temperature for development of the red pigment in tomato probably lies between 22° and 25° C (72–77° F). In one experiment, trays of calcium oxide were placed in one chamber to keep the humidity low and to take up the carbon dioxide given off by the fruit. The rate of coloration was, however, not affected.

The acceleration of the coloring process by low concentrations of ethylene is sufficiently great to make it commercially valuable, if i can be shown that other ripening processes are affected as well as color. Accordingly, samples were taken for analysis. From each lot 15 to 20 fruits were taken, and from these longitudinal segments were cut, this being thought a more accurate method of sampling than the transverse plugs used by Sando. Four hundred grams of the fresh fruit, chopped fine, plus 2 grams of $CaCo_3$, with sufficient alcohol to make a concentration of about 60 per cent constituted each sample. This was brought to boil at once and boiled 2 to 5 minutes.

The H-ion concentration and total acidity were determined on separate samples from those put away for analysis, but on segments of the same fruits. Sando's method was followed. Three hundred grams of fruit were placed in a 1000 cc. flask, made up nearly to volume with boiled distilled water, 2 cc. of toluol added, and after shaking well, allowed to stand 3 days. The clear extract was then filtered off and aliquots titrated with standard alkali using phenolphtalein as an indicator. This indicator does not give a sharp end point on tomato extract, but was the best of several tested, and gave fairly accurate results when the same amount of indicator (10 drops in 50 cc.) was used for each titration. The H-ion concentration was determined colorimetrically by the method of Gillespie on the filtered extract, and the readings so obtained checked exactly with those made

TABLE I—RIPENING OF GREEN-MATURE TOMATOES IN AIR AND IN AIR PLUS ETHYLENE GAS

Date	Test	Temperature	Variety	Number fruits	Average weight in grams	Treatment	Average number days to ripen
Aug. 3	A3	22°C.	Earliana	26	94.2	In air	11.40
	A5			27	90.2	Ethylene 1:800	6.18
	A7			27	90.7	Ethylene 1:4300	6.11
Aug. 12	B1	22°C.	Earliana	78	100.6	In air	11.31
	B2			81	96.6	Ethylene 1:800	6.71
	B3			77	100.6	Ethylene 1:4300	6.30
Sept. 4	C7	20°C.	Globe	38	98.5	In air	14.26
	C8			38	97.6	Ethylene 1:800	5.97
	C9			48	97.3	Ethylene 1:4300	6.26
Sept. 4	C4	20°C.	Stone	78	113.9	In air	13.15
	C5			76	100.0	Ethylene 1:800	6.37
	C6			72	110.5	Ethylene 1:4300	5.97
Sept. 22	D1	18°C.	Stone	69	110.4	In air	15.70
	D2			69	110.1	Ethylene 1:4300+CaO	8.60
	D3			71	109.8	Ethylene 1:4300, no CaO	8.20
Sept. 22		18°C.	Stone	26	—	In air, calyx on	16.00±0.87
				43	—	In air, calyx off	14.75±0.62
				69	—	Ethylene 1:4300, calyx on	8.66±0.19
				71	—	Ethylene 1:4300, calyx off	8.20±0.19
Oct. 12	E3		Stone	61	136.6	In air	18.60
	E1	16°C.		132	133.2	Ethylene 1:4300	12.40

on pure juice obtained by pressing the whole tomato. A preliminary test showed that both the H-ion concentration and the total acidity of the free juice of the fruit compared to the extract of the meaty pericarp, were very different, hence great care was taken in sampling to get corresponding amounts of these portions of the fruit.

A preliminary examination of samples from green-mature and vine-ripened Stone tomatoes indicated that sucrose, dextrins, pentoses, and pentosans were present in such small quantities that they were not considered further. The results on the constituents that were determined, are given in Table II.

Acidity:—In passing from the green-mature to the turning condition, there is an increase in the "active" or "true" acidity, as indicated by a drop of 0.2 in the exponent of the H-ion concentration, for all 3 varieties. Thereafter the H-ion concentration decreases, reaching a minimum in the vine-ripened fruit. With Earliana and Stone the H-ion concentration of fruit ripened in ethylene is about the same as for vine-ripened fruit; on the other hand, fruit ripened in air has a higher acidity, being the same as in the green-mature fruit when picked. With the Globe the H-ion concentration of both ethylene and air ripened fruit is higher than in the green fruit. No reason for this discrepancy is known. In general, the changes in H-ion concentration are not great, as would be expected in a well buffered system.

The total or "titratable" acidity has been calculated as citric acid, which is the conventional method of expressing the acidity of tomato. While citric acid has actually been identified in tomato recently by Kremers and Hall (4), it is probable that other constituents contribute to the total acidity. Total acidity follows the same course as the H-ion concentration, but with much broader range. The maximum occurs in the turning fruit, and the minimum in vine-ripened fruit. The acid content of air-ripened fruit is less than in green-mature, but is considerably higher than in vine-ripened fruit. On the other hand, acidity of ethylene-ripened fruits is almost as low as in vine-ripened, in the case of the Stone and Earliana. Probably one of the effects of ethylene on the metabolism of the fruit, is to accelerate the oxidation of the organic acids.

Sugars:—Reducing sugars constitute over a third of the solid substance of the tomato fruit. Digestion in boiling 5 per cent Hcl destroys about 10 per cent of this, thought to be levulose, the remaining 90 per cent being considered to be dextrose.

The sugar content increases uniformly from the green-mature to the vine-ripe condition, in agreement with the results of Sando. However, Sando reports artificially ripened tomatoes to have the same sugar content as vine-ripened fruit, whereas here we see that the artificially ripened fruits are much lower in sugar than the vine-ripened (with one exception). In Earliana and Stone the air-ripened fruits have an even lower sugar content than the green-mature fruit, and in the Globe, the sugar of air-ripened fruit corresponds to that in turning fruit. Ethylene-ripneed fruits have a sugar content somewhat higher than green-mature fruit, but still distinctly lower than vine-ripened fruit, except in Globe.

TABLE II—COMPOSITION OF TOMATOES AT DIFFERENT STAGES OF MATURITY, AND RIPENED IN DIFFERENT WAYS. CALCULATED TO PER CENT OF FRESH WEIGHT

Maturity	H-ion concentration	Total acid as citric	Reducing sugar	Starch	Total nitrogen	Soluble nitrogen	Total solids	Soluble solids
	pH	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Earliana								
Green-mature	4.3	—	2.145	.140	.1675	55.7	5.39	59.9
Turning	4.1	—	2.400	.048	.1615	58.5	5.67	64.3
Pink	4.2	—	2.532	.033	.1728	58.3	6.05	64.0
Vine-ripened	4.4	.4605	2.754	.034	.1886	64.9	6.33	67.9
Ripened in ethylene 1:800, 6 days	4.3	.5460	2.122	0	.1643	63.8	5.05	64.3
Ripened in ethylene 1:4300, 6 days	4.3	.5881	2.284	.043	—	—	5.07	65.8
Ripened in ethylene 1:800, 8 days	4.4	.4899	2.005	.063	—	—	4.93	63.8
Ripened in air, 12 days	4.3	.6441	1.900	0	.1910	64.0	5.46	60.0
Stone								
Green-mature	4.3	.8530	1.885	.277	.1860	54.3	5.94	51.2
Turning	4.1	.9430	2.308	.106	.1857	54.1	5.99	55.5
Pink	4.2	.9100	2.256	.037	.1908	63.0	5.63	60.8
Vine-ripened	4.5	.6058	2.625	.012	.2026	65.8	5.91	65.9
Ripened in ethylene 1:800	4.45	.6101	2.232	.042	.1899	61.4	5.74	61.1
Ripened in air	4.3	.6810	1.785	.009	.2071	62.2	5.54	58.4
Globe								
Green-mature	4.5	.6700	2.384	.276	—	—	6.10	51.0
Turning	4.3	.8180	2.515	.088	—	—	5.99	54.6
Pink	4.5	.7070	2.610	.026	—	—	5.80	59.1
Vine-ripened	4.65	.5860	2.750	.022	—	—	5.88	62.9
Ripened in ethylene 1:800	4.25	.6770	2.832	.033	—	—	5.61	58.9
Ripened in air	4.20	.6350	2.570	.066	—	—	5.86	61.1

*Calculated as per cent of total.

Since fruits ripened in ethylene are exposed to loss of earbohydrates by respiration only half as long as fruit ripened in air, the former may reasonably be expected to present a somewhat higher content of sugar when fully colored. The important point here, however, is that artificially ripened fruits in general, have a lower sugar content than fruits ripened on the plant. In view of the steady increase in sugar of fruits attached to the plant until fully ripe, and the absence of any extensive carbohydrate reserves in the green fruit, it may well be questioned how artificially ripened fruit could ever show much increase in sugars.

Starch:—A small amount of starch occurs in the outer cells of the pericarp of green fruits. Practically all of this disappears by the time the fruits reach the turning condition. A little starch is also found in the endosperm of the seed, even in ripe fruits, but the reserves of the tomato seed seem to be mostly protein and fat. The starch reported in these analyses was determined by digestion with saliva at 38° C. The starch reported by Sando for tomato fruit included other acid-hydrolizable polysaccharides, hence his figures are much higher than those reported here.

Nitrogen:—Total nitrogen was determined by the Kjheldahl method, modified to include nitrates. Digestion was over-night with phenol sulfuric acid. The determinations were made separately on the solid residue and the soluble fraction of the samples, but care was taken to evaporate the solid fraction to dryness before digestion. For the 2 varieties analyzed, it is apparent that there is a steady increase in total nitrogen as the fruit passes from the green-mature to the ripe condition on the vine. This is the opposite of Sando's results, who reports decreasing amounts of total nitrogen in green-mature, turning, and ripe fruits.

The proportion of the total nitrogen occurring in the soluble fraction (soluble in 60 per cent alcohol) is of special interest, for the soluble nitrogenous constituents no doubt have much to do with flavor. It is seen that the soluble nitrogen increases steadily during the ripening process, from about 55 per cent of the total nitrogen in green-mature to 65 per cent in vine-ripened fruits. In artificially ripened fruits, the proportion of soluble nitrogen is only slightly lower than in vine-ripened.

Solids.—Total solids do not vary greatly during the ripening process. However, there is an important change in the nature of the solids, for the proportion included in the insoluble residue decreases uniformly as the fruit passes from the green-mature to the vine-ripened condition. Conversely the proportion of solids occurring in the soluble fraction (60 per cent alcohol) increases during ripening, concomitant with the increase in sugars and soluble nitrogenous constituents. In the artificially ripened fruits, the soluble solids are lower than in vine-ripened fruits, but much higher than in the green fruit as picked. They are generally higher in ethylene-ripened than in air-ripened fruits.

Storage Tests

That tomato fruits harvested green and ripened artificially remain solid and sound for a longer period than vine-ripened fruits was mentioned by Duggar (1) and is a fact generally recognized by shippers. Since it has been found that coloration and other ripening processes are favorably affected by ethylene, it remained to determine if the softening of the fruit and length of normal storage life were also affected in fruits so artificially ripened.

Fruit picked in varying stages of maturity, and fruit picked green and artificially ripened in air and in ethylene, were stored in a room where the temperature varied from 55° F. at night to 70° F. in the day. Under these rather cool conditions the fruit remained sound for a surprisingly long time. However, only perfect fruits were used in the tests. Fruits having growth cracks, or abrasions due to careless handling, collapse quickly due to the growth of black mold (Rhizopus). The results of 2 experiments are given in Table III.

TABLE III—Relation of Maturity and Method of Ripening, to Storage

Variety	Treatment	Number fruits	Average number days to spoil	
			After ripening	After picking
Earliana	Picked green—air-ripened	14	25.9	37.9
Earliana	Picked green—ethylene ripened	45	26.8	32.8
Stone	Picked green—air ripened	19	14.0	28.9
Stone	Picked green—ethylene-ripened	80	15.0	26.1
Stone	Picked turning—air-ripened	27	14.1	22.7
Stone	Picked pink—air-ripened	16	16.0	19.7
Stone	Picked ripe—vine-ripened	12	11.6	11.6

Apparently, fruit ripened by exposure to ethylene for 6 days will keep as long as that air-ripened in 12 days. When the length of storage life is considered from the time of picking instead of from the time of attaining full red color, however, the air-ripened fruit shows a slight superiority.

Considering the fruit picked in different stages of maturity, it is evident that vine-ripened fruit has much the shortest storage life, and this increases in length the less ripe the fruit is when harvested.

The softening process leading to breakdown and decay in fruit is thought to be due to the increase in soluble solids and the conversion of the calcium pectate of the middle lamella to "pectic acid." This softening process is much slower in fruit harvested green and artificially ripened either in air or in ethylene. The hastening of ripening with ethylene has not notably accelerated softening, hence has not shortened the storage life of the fruit.

Summary and Conclusions

The ripening process of fruit attached to the plant in the 3 varieties studied is characterized by the following changes:

Hydrogen-ion concentration and total acidity increase from the green to the turning stage, then decline to a minimum in the ripe fruit.

Sugars, chiefly dextrose, and total nitrogen increase steadily from the green-mature to the ripe conditions. Starch practically disappears in the earliest stages of ripening.

The proportion of the total nitrogen in soluble form increases during ripening.

Insoluble solids decrease and soluble solids increase markedly during ripening.

There is evidently a movement of substances from the plant into the fruit throughout the ripening process. The analyses show that fruit picked in the green-mature condition and ripened artificially, are poorer in sugar and in total nitrogen, than those vine-ripened.

Ethylene gas in concentrations as low or lower than 1: 4300, greatly accelerates the development of the red pigment. Other ripening processes, the destruction of starch and of organic acids, and the conversion of insoluble nitrogen to soluble forms, are also accelerated.

The type of changes affected by ethylene in the tomato, indicates that this substance, which is chemically a reducing agent, acts as a stimulus to the normal oxidative processes in the fruit.

The softening process, associated with ripening of fruits on the plant, is much less marked in fruits ripened artificially in air or in ethylene. Such artificially ripened fruits have about the same storage life, and this is considerably longer than in the case of vine-ripened fruits.

It is believed that the method of ripening green-mature tomatoes in ethylene will result in the marketing of tomatoes more nearly comparable to vine-ripened fruit, than do present methods of ripening such fruit in air. The new method also involves an important saving in time and minimizes the chances of loss through shrinkage and decay. This will represent an economy to receivers and distributers of southern and western tomatoes. It is thought, too, that eastern and northern growers of tomatoes for local markets can very materially increase their output of extra early product by picking the green-mature fruit and ripening it artificially.

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Some Changes in the Relations of Plants and Soil Caused by Sterilization of Soil with Steam

By ORA SMITH, *Iowa State College, Ames, Iowa.*

THIS study was started to secure some information as to the changes in some of the physical factors following steaming of soil which may influence the growth of roots in steam sterilized soil. A comparative study was made of steamed and unsteamed soil in regard to: first, the water absorbing and holding capacity; second, the water relations between tomato plants and the soils; third, water supplying power of the soils; fourth, wilting coefficients; and fifth, changes in the concentration of the soil solutions and in the sap of the plants grown in the 2 soils.

It has been shown by Lafferty (4) and also the writer (8) that as a result of sterilizing soil with steam the root systems of tomato plants grown in this soil are of a much finer texture, more fibrous and apparently possess a greater total absorbing area. Russel and Petherbridge (7) also have observed this fact.

Johnson (3) found that a virgin sandy loam heated to 115°C. took up water only one-half to one-eighth as fast as the unheated soil. Russel and Petherbridge (7) observed that soils heated to 100°C. appear to become more moist than unheated soils when both received the same amount of water. Pickering (6) found the water capacity or absorbing power of steamed soil to be less than the unsteamed. Lyon and Bizzell (5) report that Richter found heating a soil increased its absorptive power for water.

I. WATER ABSORBING AND HOLDING CAPACITY

Two methods were used to secure information on the water absorbing and holding capacity of the steamed and unsteamed soil.

A portion of the soil used in the following experiments was treated in an autoclave at 15 pounds pressure and 132°C. for a period of 45 to 60 minutes. Other soil was taken from the greenhouse bench where it had been steamed by the inverted pan method for 45 minutes at 60 to 80 pounds pressure. After steaming, air dried soil was used in every case.

(a) Equal quantities of steamed and unsteamed soil were placed into separate one-liter beakers. The Livingston porous cup auto-irrigator apparatus was inserted in the soil. The soil was compacted equally and evenly by dropping the filled beakers, 5 times, a distance of 1 inch. The reservoirs were filled at irregular intervals and the amount of water absorbed by each soil was recorded. The experiment was continued until absorption was almost constant from day to day.

In the second series the auto-irrigators that had been in the steamed soil were placed in the unsteamed soil and vice versa to eliminate any differences due to unsimilarity in the cups.

(b) Hilgard pans of 1 centimeter depth were used for the determination of the water holding capacity of the soils after the soils

had been sifted through one-sixteenth inch mesh sieve. The average total amount of water absorbed by the steamed soil by the auto-irrigator method during a period of 16 days was 255.0 c.c. and by the unsteamed soil 350.5 c.c. In the second series with the irrigators exchanged the average total absorption of the steamed soil during a period of 11 days was 273.0 c.c. and of the unsteamed soil 352.5 c.c.

The average percentage of water holding capacity of the 4 different samples of soil as determined by the Hilgard method are as follows:

Steamed soil 54.57 per cent water holding capacity

Unsteamed soil 60.07 per cent water holding capacity

When the apparatus in (a) was taken down, moisture determinations of the soils showed the unsteamed soils to have a higher percentage of moisture than the steamed soil.

Beginning with the initial readings and until the experiments were discontinued, the results of both series showed that the unsteamed soils absorbed more water from the cups although the absorption rates tended to approach each other toward the end of the experiment. The initial readings showed that the unsteamed soil absorbed approximately 50 per cent more water than the steamed soil, but the succeeding readings did not uphold this percentage and the margin of difference gradually dwindled to 7 per cent, but in no case did the steamed soil absorb more water than the unsteamed soil.

II. Water Relations Between Tomato Plants and the Soils

Series I.—Equal amounts of soil were brought up to 30 per cent moisture content and placed in 1 liter beakers. A Livingston auto-irrigator cup was placed in the center of each beaker, filled with water and attached so as to draw water from a bottle by capillarity. Tomato plants 14 days old and 2 inches tall were used. One plant was set in each beaker midway between the irrigator cup and the edge of the beaker. The surface of the soil was sealed over with a layer of paraffin to exclude evaporation from the soil surface. The beakers were arranged around a torsion balance in such a way that they could be weighed without moving the reservoir bottle.

Series II differed from Series I in that aluminum pots of about 1 liter capacity were used instead of beakers and 3 tomato plants instead of 1 were grown in each pot.

To compare the rate of transpiration of the plants with that of evaporation from a standardized porous cup atmometer, an atmometer arranged to draw water from a burette was set up beside the plants. At various intervals the plants and pots were weighed, the reservoirs refilled, the atmometer reading taken, the burette refilled, and the amount of transpiration calculated. Series I was continued for a period of 44 days. Series II was discontinued after a period of 51 days.

At the close of the experiment the plants were removed, the weights of the tops and the roots obtained, the total leaf area measured with the polar planimeter, the loss of water per square inch of leaf surface, and the ratio of weight of tops to weight of roots calculated.

A study of Table I shows that the plants grown in the steamed soil absorbed more water, transpired more and made a greater root, top and total growth and total leaf area than the plants grown in the unsteamed soil. The total amount of water absorbed by the soil and transpired by the plants in the steamed soil was more than double the amount absorbed by the soil and transpired by the plants in the unsteamed soil. The average total loss by transpiration from each plant in the steamed soil was 3484.3 c.c. and from the plants in the unsteamed soil 1674.5 c.c. The average amount of water absorbed by the steamed soil from the irrigator cup was 3117.3 c.c. and by the unsteamed soil, 1499.5 c.c. The evaporation from the atmometer during the same period was 668.5 c.c. or 64.27 c.c. per square inch. The amount of transpiration per square inch of leaf area of the plants in the steamed soil was practically the same as that from the plants grown in the unsteamed soil. The plants grown in the steamed soil had a smaller average ratio of weight of tops to weight of roots than the plants grown in the unsteamed soils indicating as shown by Table I that the roots of the plants in the unsteamed soil had not increased as greatly as the tops.

A study of Table II will reveal that the plants grown in the steamed soil had a greater weight of tops, roots, total weight, and greater total leaf area than the plants grown in unsteamed soil. The average total amount of water absorbed per pot of 3 plants during the period of this experiment was 2134.6 c.c. for the steamed soil and 1230.85 c.c. for the unsteamed soil. The average total loss by transpiration of each pot was 2140.2 c.c. for the steamed soil and 1235.6 c.c. for the unsteamed soil. The loss of water by transpiration per square inch of leaf area was almost identical for the plants in each kind of soil. The ratio of weight of top to weight of root was narrower for those plants grown in the steamed soil than for those grown in unsteamed soil. During the first 11 days of the experiment the unsteamed soil drew more water from the irrigator cup than did the steamed soil. This may have been due to the greater water absorbing power of the unsteamed soil, for during the remainder of the period (40 days) the steamed soil took up a greater amount of water than the unsteamed soil, the total amount absorbed during the entire period of the experiment being 75 per cent more than that absorbed by the unsteamed soil and plants.

III. Water Supplying Power of Steamed and Unsteamed Soil

Air dried steam sterilized and unsteamed soils were placed into separate battery jars and compacted equally. Water was added to bring the soil up to the saturation point and all excess poured off. The Livingston auto-irrigator with the walls infiltrated with a semipermeable membrane of copper ferrocyanide was then inserted in the soil in the center of the jar. The cup was filled with a five-weight molecular cane sugar solution and attached by tubing to a 50 c.c. burette graduated in tenths of a cubic centimeter. The cups were standardized before using. The action of this apparatus is supposed-

TABLE I—COMPARISON OF THE AVERAGE GROWTH OF TOMATO PLANTS GROWN IN STEAMED AND UNSTEAMED SOILS

	Weight of tops grams	Weight of roots grams	Total leaf area square inches	Amount of water absorbed by soil	Amount of water transpired by plant	Transpiration per square inch of area	Ratio top to root
Steamed soil.....	144.5	38.0	188.4	3117.3 c.c.	3484.3 c.c.	18.49 c.c.	3.7 to 1
Unsteamed soil..	80.5	16.0	88.8	1499.5 c.c.	1674.5 c.c.	18.85 c.c.	5.03 to 1

TABLE II—COMPARISON OF THE AVERAGE GROWTH OF TOMATO PLANTS GROWN IN STEAMED AND UNSTEAMED SOILS. SERIES II—THREE PLANTS PER POT

	Weight of tops grams	Weight of roots grams	Total leaf area square inches	Amount of water absorbed by soil	Amount of water transpired by plant	Transpiration per square inch of area	Ratio top to root
Steamed soil.....	74.7	27.25	287.1	2134.6 c.c.	2140.2 c.c.	7.43 c.c.	2.93 to 1
Unsteamed soil..	45.3	10.3	165.8	1230.85 c.c.	1235.6 c.c.	7.42 c.c.	4.43 to 1

ly somewhat similar to the intake of water through the roots of a plant. This test was run in triplicate.

TABLE III—AMOUNT OF WATER PASSING THROUGH SEMIPERMEABLE MEMBRANE BY OSMOSIS

	Soil 50 per cent moisture	Soil 46 per cent moisture	Soil 49 per cent moisture
Steamed soil	18.4 c.c.	10.90 c.c.	18.6 c.c.
Unsteamed soil	14.9 c.c.	5.64 c.c.	10.7 c.c.

Table III shows that in each case the cups in the steamed soil absorbed more water through their walls than did the cups in the unsteamed soil. The steamed soils of 50 per cent and 49 per cent moisture gave practically the same amount of water change, but the unsteamed soils showed some variation. In the trials with 46 per cent saturated soil the wide differences between the movement of water from the steamed soil and the unsteamed soil was probably due to a break in the membrane during osmosis. A test showed that sugars had entered the soil only in this one case by a break in the membrane. The steamed soil supplied from 23 to 73 per cent more water to the sugar solution in the cup by osmosis than did the unsteamed soil.

IV. Wilting Coefficients of Steamed and Unsteamed Soils

Tomato plants similar to those used and described in the previous tests were transplanted into 4 inch earthenware pots, encased in 4½ inch aluminum pots and the tops of the pots covered with oiled cloth and paraffin to exclude all evaporation from the soil. These plants were grown similarly to the Briggs and Shantz (1) method. The plants were removed from the pots at the first signs of permanent wilting (50 to 52 days old) and the wilting coefficients of the soil calculated.

	Wilting coefficient
First series	
Steamed soil	4.80 per cent
Unsteamed soil	5.74 per cent
Second series	
Steamed soil	4.63 per cent
Unsteamed soil	5.22 per cent
Third series	
Steamed soil	5.06 per cent
Unsteamed soil	6.18 per cent

The wilting coefficient of the steamed soil was in every case lower than the wilting coefficient of the unsteamed soil indicating that the plants growing in the steamed soil can use a larger percentage of the moisture in the soil and will not reach the critical wilting point as soon as the plants growing in unsteamed soil. Every plant growing in the unsteamed soil showed signs of permanent wilting 24 to 36 hours before those plants growing in steamed soil.

V. Changes in the Concentration of the Soil Solutions and in the Concentration of the Juice of the Plants Grown in the Two Soils

Determinations were made of the concentrations of the soil solutions and expressed plant juice with the Beckman thermometer and freezing point apparatus. One hundred grams of air dried soil was mixed with 100 c.c. distilled water, shaken for 20 minutes and filtered, the resulting solution being used.

TABLE IV—Freezing Point Determinations of Soil Solution*

	Freezing point	Depression of freezing point	Osmotic pressure in atmospheres
Distilled water.....	4.35°C.	——	——
Steamed soil.......	4.26°C.	0.09°C.	1.086
Unsteamed soil....	4.30°C.	0.05°C.	0.603

*Average determination of 18 samples.

Table IV shows that steaming a soil in every case increased the concentration of the soil solution as shown by the freezing point method. The average increase in osmotic pressure in atmospheres of steamed soil solution was 0.483 over the unsteamed soil solution.

Bonny Best tomato seedlings 16 days old were transplanted in 4 inch pots containing steamed soil. A similar group was planted in unsteamed soil. At the end of 34 days the soil was washed from the roots of the plant and the juice expressed from the entire plant.

TABLE V—Freezing Point Determinations of Expressed Tomato Juice*

	Freezing point	Depression of freezing point	Osmotic pressure in atmospheres
Distilled water.....	4.162°C.	——	——
Steamed soil.......	3.627°C.	0.535°C.	6.442
Unsteamed soil.....	3.715°C.	0.447°C.	5.386

*Averages for 12 samples.

In every case the juice of the plants grown in steamed soil lowered the freezing point more than the juice of plants grown in unsteamed soil indicating a more concentrated juice from the plants grown in the steamed soil. Table V shows that the average freezing point lowerings of the juice of plants grown in steamed soil was greater than of those plants grown in unsteamed soil. This indicates that the concentration of the soil solution may have a tendency to affect the concentration of the plant juice of the plants grown in these soils. Tables IV and V indicate that the greater the concentration of the soil solution the greater also the concentration of the plant juice of the plants grown in these soils.

Discussion

Czermak (2) showed that steaming the soil had a tendency to coagulate the colloidal soil particles. This reduces the number and increases the size of the individual masses which, in turn, increases the amount of interstitial space as there are a smaller number of points of

contact between the soil granules. This reduces the surface area of the particles which is the water holding surface and, therefore, reduces the capacity of the soil to hold water. This may also explain the more rapid movement of moisture throughout the soil from the irrigator cup in the unsteamed soil. Owing to the finer state of division of the unsteamed soil mass the films of moisture surrounding the soil granules merge sooner and are pulled together at the points of contact with a greater force than that exerted by larger particles and further separated surfaces. This may partially account for the greater water holding and water absorbing capacity of the unsteamed soil over the soil that has been steam sterilized.

The limit of the capacity of any soil for water is reached when the surface tension holding the water in the capillary spaces is no longer able to overcome the force of gravity acting on the mass. Therefore, the relative water capacity of the 2 soils depends principally on the number and size of the capillary spaces.

Part III of this experiment shows that the water is drawn out of the soil and enters the porous cup through the semipermeable membrane by osmosis. This resembles somewhat the process of water absorption by roots. This water supplying power of the soil depends on resistance to water absorption offered by the soil layer adjacent to the absorbing surface. This depends, first, upon the nature and arrangement of the soil particles in this active layer and second, on the water content of this layer of soil. A mechanical analysis of these soils would not necessarily be of great value as the changes in the shape and arrangement as well as the size of the particles would influence the results.

Each soil particle in a saturated soil is enclosed in a film of moisture which is held in place by capillarity, adhesion, and cohesion. Steaming increases the size of the particles of soil. The smaller the particles of soil the more tenaciously the water films cling to the soil particles and capillary spaces. Hence, a steamed soil of larger soil particles holding its soil moisture more loosely will give it up to the artificial or natural root more easily and readily.

As brought out by the experiments dealing with the water relations between tomato plants and the steamed and unsteamed soils the total transpiration appears to be a measure of the growth of a plant. But there is some factor which in every case caused the plants grown in steamed soil to gain the initial advantage in growth over the plants grown in unsteamed soil. Steaming the soil increases the concentration of the soil solution probably by making the plant nutrients more available. It may be these added available plant nutrients that aid the plants grown in the steamed soil. Due to the greater water supplying power of steamed soil, and the lower wilting coefficient of steamed soil showing more efficient and complete use of soil water, the writer believes this increased growth is partially due, however, to the changes in the texture and other physical characters of the soil which are brought about by steaming.

The results of the work on wilting coefficients as shown in Part IV indicate that the steamed soil supplies the water to the roots of the

tomato plants in a more efficient manner than does the unsteamed soil. Also by having a less extensive and less efficient root system, the plants grown in the unsteamed soil are unable to draw moisture from all parts of the soil as easily and completely as the root systems of the plants grown in the steamed soil.

Summary

Check or unsteamed soil absorbs more water from an auto-irrigator than steamed soil and also has a greater water holding capacity than steamed soil.

Steamed soil by osmosis gave up more water to a sugar solution than did the unsteamed soil.

Wilting coefficients of steamed soil were lower than the wilting coefficients of the unsteamed soil.

Tomato plants grown in steamed soil absorbed more water, transpired more water, and made greater root, top, and total growth and total leaf area than those plants grown in unsteamed soil.

Steamed soil had a more concentrated soil solution, as shown by the freezing point method, than unsteamed soil. The concentration of the plant juice of plants grown in steamed soil was greater than of those plants grown in unsteamed soil.

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Pollination and Fruiting Habit of the Watermelon

By J. T. Rosa, *University Farm, Davis, Calif.*

PROBABLY none of our major truck crops has received less systematic investigation than the watermelon. Yet this plant offers many fascinating aspects for study, and problems of practical importance to be attacked by plant breeding methods. In connection with the preliminary work on the study on inheritance in the watermelon, some observations have been made of the pollination and fruiting habits.

The plant consists of a trailing stem with many axillary branches. The flowers are solitary in the leaf axils, arising opposite the tendril which persists until the fruit is mature. Practically all of the leaf axils on all the branches of the plant bear flowers. The sexes are not segregated on separate branches as in cantaloupes and the other members of *Cucumis melo* (1). Generally, every seventh axil on a stem bears a pistillate or hermaphroditic flower, the intervening axils producing staminate flowers only. Flowering is continuous throughout the growing season, and there is no evidence of a well marked cyclic sterility as there is in cantaloupe (1). While many, perhaps the majority, of the pistillate flowers fail to set fruit, this abortion seems to prevail about equally on the different regions of the stem.

At Davis, California, during the month of July, both staminate and pistillate flowers open usually between 6:30 and 7:30 a. m. When the nights are cool, 55–60°F, the flowers are not completely open until 8:00 a. m. When the nights are somewhat warmer, the flowers open earlier. Bees have not been observed in the field earlier than 7:00 a. m. The flowers close in late afternoon of the same day in which they open. Pollination in nature seems to be accomplished largely by bees, though other insects, especially the cucumber beetles (*Diabrotica sp.*) play a part. Wind pollination is unlikely.

The anthers dehisc somewhat before the corrolla expands fully in all varieties except one of the wild citrons, which dehisces about 2 hours later.

With reference to sexual arrangement, the manuals usually describe the watermelon as being monoecious. Bailey (2) states that in the genus *Citrullus* rudiments of stamens are found in the pistillate flowers. However, examination of 16 American varieties of watermelons and citron-melons grown at Davis, California, and a much larger collection in the trial grounds of the Robinson Seed Company at Modesto, California, showed that neither of the above statements is entirely correct. All varieties bear purely staminate flowers without a rudimentary ovary (as there is in the closely related *Citrullus colocynthis*, according to Kraemer (3). Many varieties bear also purely pistillate flowers without trace of stamens. Varieties in this class are: Klondyke, Black Seeded Chilian, Excell, Irish Grey, Tom Watson, Conquerer, Red Seeded Citron, Green Seeded Citron, and a citron found growing wild near Turlock, California. A smaller

group of varieties bears hermaphroditic flowers in place of the purely pistillate ones. These generally have 3 well developed stamens attached to the base of the corrolla. These produce an abundance of pollen which cannot be distinguished from that shed by the anthers of the staminate flowers. Varieties of this andro-monoecious class are Black Seeded Angeleno, White Seeded Angeleno, Red Seeded Chilian, Baby Delight, Winter Queen and an unknown variety found in Imperial Valley, called Snowball. In the White Seeded Chilian variety some plants bore pistillate flowers, others bore hermaphroditic flowers. This was apparently an impure strain.

To test the fertility of the hermaphroditic flowers a number wére bagged prior to anthesis. Some of these were left undisturbed, without hand pollination, while the bags were removed from others during the day and each stigma dusted with pollen from an anther born in the same flower. The results are given in Table I.

TABLE I—FRUIT SETTING IN HERMAPHRODITIC FLOWERS OF WATERMELON

Variety	Not hand pollinated			Hand pollinated		
	Bagged	Set	Matured	Bagged	Set	Matured
B. S. Angeleno....	27	4	0	2	1	1
B. S. Chilian.....	25	0	0	5	3	1
Snowball.........	6	0	0	2	2	2
Winter Queen.....	22	1	0	3	2	1

The ovaries of hermaphroditic flowers not hand pollinated generally withered within a day or two without enlarging. A few appeared to set and grew to 1 to 3 inches in diameter before degeneration set in, but of the 81 flowers bagged, not 1 matured a fruit. When similar flowers were hand pollinated by their own pollen, fruit set readily and matured with a normal yield of seed. The same situation exists as in cantaloupe—the hermaphroditic flowers are self-fertile, but pollination does not take place in bagged flowers, because of the sticking of the pollen to the anther following dehiscence. The selfing of hermaphroditic flowers may be much more common in nature when the flowers are exposed to insect visitation and air movement. The extent to which cross-pollination occurs between unprotected flowers of adjacent varieties has not been determined; that it is a very common cause of varietal mixture in varieties having pistillate flowers, is obvious; and it is reasonable to suppose that such mixture is less likely in varieties bearing hermaphroditic flowers. Hence the hermaphroditic habit is considered desirable in melons, and will be so considered in the breeding work.

In view of the reported occurrence of parthenocarpy in several of the cucurbitaceae, it was of interest to determine if autonimic or vegetative parthenocarpy occurs in the watermelon. Emasculated hermaphroditic flowers, and the pistillate flowers of certain varieties, were bagged just before anthesis, as follows: Angeleno, 3; Chilian, 3; Snowball, 2; Klondyke, 18; Excell, 10; Citron, 2. Of these 38 flowers, 7 showed some subsequent enlargement of the ovary, but within 10 days, all of these died. There is little tendency toward parthenocarpy in the common American varieties.

In the plant breeding work flowers are bagged between 6:00 and 7:00 a. m. Where pistillate forms are to be selfed, the adjoining staminate flowers may also be covered to insure a supply of uncontaminated pollen which is transferred to the stigma an hour or 2 later. Pollination can frequently be performed at the time the flowers are first bagged, however, since the pollen is shed somewhat before the corrolla opens. The staminate flowers in the axil just below the pistillate flowers always open on the same day and about the same time. When the hermaphroditic varieties are used in crosses, emasculation is performed the preceding afternoon although this can be safely done in early morning at which time it is easier to select flowers which will open that day. One pound manila paper bags are used, and these are removed 2 days following pollination, although the fruit will develop satisfactorily if the bags are left on. All the varieties of watermelons and citron melons tested have proved both self- and inter-fertile.

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Types and Varieties of Celery

By PAUL WORK, *Cornell University, Ithaca, N. Y.*

MANY, perhaps most, of the changes which horticultural workers, in common with the rest of the world, observe from year to year are changes in emphasis. Very wisely we have laid great stress upon the establishment of new knowledge and we may reasonably hope that the gains we have made in research will not be lost when we enter again upon periods of teaching and extension emphasis. Within the investigational field there are differences in emphasis, perhaps even fads. Systematic science is just beginning to find its place in relation to research enterprise. Its position is two-fold, first as a research activity in itself and second as a contributor to sound results in other research.

The standing of systematic study as productive research depends upon the character of the work done. The jotting of notes in the trial ground and their subsequent publication is not research. It is mere data-taking and the product is unfinished. The establishment of truth about varieties requires care in the selection of material for trial and precision in its handling; a thorough study of plant characters to evaluate their usefulness for systematic purposes; accurate

observation and recording of characters, using actual measurements as far as may be practicable; the use of definite and precise methods in reducing field notes to finished verbal descriptions; the orderly arrangement of varieties and names according to the principles of natural and artificial classification.

Systematic research is necessary for any real progress in bringing order out of the chaos of vegetable varieties and nomenclature though efforts based on consensus of opinion will help for the time being.

The place of systematic study in relation to other research requires no argument, though the need for its results is often overlooked. The specialists in animal nutrition have set us a good example, for the rat and the guinea pig have been extensively studied in order that their results may be reliable. There is a large book dealing with the rat. To illustrate the importance of knowledge of varieties in our own field, the writer may be pardoned for referring to his own studies in tomato nutrition.* In all of the work a good uniform strain of Bonny Best was used. No amount of nitrate was sufficient to cause running to vine. H. F. Hall has since called attention to the fact that he has never seen this variety so behave although Stone, Matchless, and Enormous do. We must vary the variety factor betfore we can fully understand this phenomenon of excessive vegetative development. Now, suppose that, for apparently sufficient reasons, the variety had been changed between the two years of experiments. Suppose also someone had undertaken to check the results, using Matchless for the work. You may guess the possible results. To state the case in a word, the research worker must know the varietal characters of the material he uses.

A study of the types and varieties of American celery extending over a period of several years, has afforded opportunity to examine systematic methods with some care and a brief report of the work will offer occasion for some tentative suggestions. Too little has been done to justify dogmatic statements. It is hoped that these observations may stir others to better conclusions, of which the writer will be delighted to avail himself.

Selection of Material

Before gathering material for trial a list of all varieties of commercial significance in this country was drawn up with the aid of two seedsmen who were most generous in their cooperation. Samples were procured from sources that would be as nearly authentic as possible, usually from the producer of the seed, though sometimes from the introducer or from a seedsman who makes a specialty of a variety or who controls a source of his own. Several stocks of each variety were tested, but unnecessary duplication of stocks was avoided by seeking original sources rather than by using miscellaneous retail catalogues. Most seedsmen when assured confidential treatment for source-information, were very liberal.

*Work, Paul. Nitrate of soda in the nutrition of the tomato. Cornell Univ. Memoir 75. 1924.

The trials of the first few years yielded a rough knowledge of types so that it was possible to reduce the number of samples to 2 or 3 for each variety. One sample was finally adopted as the type-sample. The long life of celery seed is favorable for this. In choosing type-samples it was necessary to consult growers, seedsmen, catalogues and other sources of information. A survey-questionnaire was used to advantage.

Relative Usefulness of Characters

Plant characters vary greatly in their usefulness for systematic purposes. For example, leaf-patterns were rather persistently studied, but they proved of little service, although some varieties show fairly consistent deviations from others in this respect. This does not mean that further study may not yield results. On the other hand, the cross sections of petioles proved of considerable value. The form was recorded by slicing them at 3 different points and using the cut surfaces to make an ink impression. They range from the extremely thick type of Emperor to the thin form of White Plume.

Usefulness of characters depends upon the readiness with which they can be definitely observed and the consistency with which they persist throughout the stock of a given variety, in successive as well as single seasons. The spread and outline of the base of the petiole was considered, but variation between outside and heart of plant outweighed varietal differences.

This critical examination of characters serves to eliminate a good many that appear on description sheets made for completeness rather than usefulness, and thus the labor of note-taking as well as the mass of material to be handled, is reduced. The most useful characters in celery, listed without reference to their relative merit, seemed to be:

Number of leaves.	Development of heart.
Weight of plant.	Blanching, ease and color.
Circumference of plant.	Color of foliage.
Height of plant.	Cross section of leaf stalk.
Length of petiole.	Pithiness.
Earliness.	Suckers.
Habit (erect or spreading).	Keeping.

Note Taking

Systematic research revolves about the taking of notes. Endless notes may be made without much being learned but real accomplishment is impossible without good note taking.

Most of us began our systematic work with an apple before us and a paper bearing long lists of terms to represent every existing or imaginable variation. We usually described each variety in entirety before turning to the next, and the poor word "medium" was sadly overworked. We now find it better to take a character at a time and observe it in all varieties, or in a block of samples, before taking up another character. In this way there is less tendency for our standard

for a given term to drift. Certain deviations from this practice are permissible after the limits of terms are well established in the mind, especially where actual measurements are made.

The tabular form of note sheet in which sample numbers appear at the side and characters at the top or vice versa, lends itself well, and it has the advantage of keeping all notes before the eye of the worker without the necessity of turning pages. Measurements and symbols serve to conserve space. In most cases 3 or 5 different degrees of a character are sufficient. For example size may be expressed as very small, small, medium, large, very large. For noting, each of these may be represented by a number from 1 to 5, thus establishing a rating scale. In this way data taken under the varying conditions of different seasons may be rendered comparable. Numbers can also be assigned to forms, colors or other characters. For example, red, 1; yellow, 2; white, 3. The code may be carried with the terms at the side of the sheet for beginners but the worker soon passes the need for this.

	Sample				
	18	23	24	26	35
Height, cm., average of 10	9.2	12.3	10.5	13.0	13.3
Weight, gms., average of 10	435	615	460	880	470
Habit: spreading, 1; medium, 3; erect, 5	5	4	4	5	1
Keeping: rated 1, very poor to 5, very good	1	2	5	3	2

It is absolutely essential that the circumstances of noting and the limits of each term be fully recorded. Otherwise the worker forgets and one year's notes are not comparable with those of the succeeding season. To illustrate such a record as part of this study 15 plants were taken from the row as they stood. The 10 best were chosen and undeveloped outside leaves were discarded. The count of leaves proceeded from the outside to a point where the heart was one-half inch in diameter.

The use of actual measurements in note taking seems to present an ideal to be striven for as far as is feasible. The following illustrates the form of noting measurements and definitely recorded characters.

SAMPLE 204—OLD STRAIN, GOLDEN SELF BLANCHING

											Average of 10
Number of leaves	9	9	8	9	11	9	9	8	11	9	9.2
Weight of plant	400	450	400	350	500	450	500	350	600	350	435 grams
Circumference of plant	6	7	6	6	7	6	7	6	7	6	6.4 inches
Height of plant	20	19	18	18	19	20	21	18	20	16	18.9 inches
Length of petiole	7	7	7	7	7	7	7	6	7	6	6.8 inches

P O Hb E Hr D2–3, Ht 3 B 5 C Y

CODE: P = Number pithy plants in 10. Hb = Habit, E = Erect; M = Medium. S = Spreading. Hr = Heart. D = Diameter, rated 1–5. 1 is about three-fourths inch. Ht = Height of joint of outer well-blanched leaf, rated 1–5; 3 is about 5 inches, et cetera.

Figures of this sort are not to be accepted as hard and fast quantitative data. There were no repetitions to eliminate soil variation,

though it is not believed that this was great in the small area involved. Individual plant variations are too great to yield satisfactory probable errors. However, it is believed that such figures offer a better basis for rating samples than mere eye observation.

This method was tried out in 1921. The crop of 1922 was very poor, but comparable records were made in 1923 and 1924. Taking 5 measured characters for 15 type-samples, each representing a variety, or a total of 75 records, it was found that ratings on a scale from 1 to 5 for the 2 seasons agreed in 36 cases, they deviated by 1 place in 33 cases and by 2 places in but 6 cases. This suggests that the method has definite possibilities, though it is still in crude form. Perhaps we will develop a full statistical technique using probable error in judging the worth of our figures, for the determination of trueness to type in vegetables. At the same time it should not be expected that we will be able to place full reliance upon numerical data. Results must be interpreted in the light of full verbal notes and recourse should be had to the less formal observations of growers and seedsmen. After all the element of personal judgment based on thorough familiarity with the material is an essential factor. The study should be systematic, but not mechanical.

In this study verbal notes include many points that do not lend themselves to more formal recording, but which play important parts in building the final description. Prominent among these are the characteristics of the ribs. The whole gamut of performance characters—yield, earliness, evenness of maturity, keeping quality and the like—have well nigh evaded us in the crudeness of our observations. The same may be said of the special characters of adaptation to local soil and climatic conditions, or to canning and other uses, or to trade demand. Yet, after all, these are of even more importance to the grower than the type characters with which we have been most concerned because they are most readily observed.

Conclusions

Time fails for more than the briefest presentation of conclusioos. The reduction of quantities of notes to concise type descriptions has yielded the following list, still in tentative form, intended to include all the varieties which are important in this country and for which there is significant need.

STANDARD VARIETIES	SECONDARY VARIETIES
Golden Self Blanching	White Plume
Old Vilmorin strain	Columbia } one to be
New Vilmorin strain	Emperor } chosen
Golden Plume strain	Schumacher
Easy Blanching	Boston Market
Giant Pascal	French Success
	Winter King
	Winter Queen

Many other names are to be listed as strains, synonyms or varieties of minor significance, together with such brief characterization as may be necessary for their demarcation where differences exist.

Horticultural Groups of Cucurbits

By E. F. CASTETTER, *Iowa State College, Ames, Iowa.*

DURING the past few years the writer has made a study of, and carried on experiments with, the three commonly cultivated species of Cucurbita; viz. Cucurbita pepo, Cucurbita maxima and Cucurbita moschata. A total of 67 varieties were studied with reference to their vegetative and reproductive characters, with special attention to the fruit. Of these varieties 29 were found to belong to C. pepo, 25 to C. maxima and 13 to C. moschata.

The 3 species of Cucurbita may be readily distinguished from each other by certain outstanding characteristics, as follows:

C. pepo has stongly lobed and distinctly prickly leaves, as well as hard, grooved fruit stalks and hard shelled fruits.

C. maxima has rather kidney shaped, rough, hairy leaves, cylindrical, soft, fleshy fruit stalks and either soft or hard shelled fruits.

C. moschata has soft hairy or smooth, rounded or pointed-lobed leaves with white spots at intersections of veins. The fruit stalk is either slender and flaring at the attachment to fruit, or thick and not flaring and either hard or nearly so. The shell may be soft or hard. This species is also distinguished by seeds with a tan colored, more or less fringed, margin.

From the horticulturist's viewpoint there may be recognized within the 3 species of Cucurbita a number of more or less well defined types or groups, each comprising a number of varieties. In working out these groups the writer has respected as far as possible the botanical relationships of the varieties and it has been found possible in the grouping to maintain their species relationship throughout. Since this grouping is for the purpose of convenience and utility, however, it has been found necessary in a few instances to use artificial characteristics in limiting the groups.

The following groups in the genus Cucurbita are for the most part based on fruit characteristics. Wherever possible, however, vegetative characteristics are also employed.

CUCURBITA PEPO

Group I. Field and Pie Pumpkin. Characterized by yellow, grooved fruits, either oblong, or round and flattened at both ends. While the Mammoth Tours is mottled yellow and green in color in contrast to the plain yellow of the other varieties of the group, it has been placed here because of its other similar characteristics. The Sandwich Island is vegetatively much coarser than the other varieties, but is grouped here on account of the fruit similarity.

Connecticut Field	Winter Luxury
Kentucky Field	Fort Berthold
Mammoth Tours	Golden Oblong
Sandwich Island	Omaha
Small Sugar	

Group II. Scallop. This group is sharply defined by uniform fruit and vegetative characteristics. Fruit is flat, scalloped around the edge and is primarily for summer use. Although the fruit of Early Mandan is not scalloped its other characteristics are sufficiently typical to bring it under this group. All varieties are of the bush type.

Early White Bush Scallop	Early Yellow Bush Scallop
Mammoth White Bush Scallop	Golden Custard
Long Island White Bush Scallop	Early Mandan

Group III. Summer Crookneck. The varieties of this group may be recognized by the warty fruits with long curved necks and by a strictly bush habit of growth.

Yellow Summer Crookneck	White Summer Crookneck
Giant Summer Crookneck	

Group IV. Vegetable Marrow. The feature typifying this group is the long club shape of the fruits, that is, gradually tapering from blossom to stem end. The fruit color is white, green, or green and yellow striped with smooth skin. Vegetatively the group is not homogenous, having both bush and running varieties.

Cocozelle	Long White Marrow
Zucchine	White Vegetable Marrow.
Green Vegetable Marrow	

Group V. Fordhook. The fruit of this group is characteristically short club shaped and longitudinally grooved. There are both bush and running varieties.

Fordhook	Delicata
Fordhook Bush	English Cream Marrow

Group VI. Table Queen. Fruit small, rather acorn shaped, deeply grooved. Vegetatively the 2 varieties of this group are unlike; although the Panama is not identical in shape with the Table Queen, it is more closely related to it than to any other variety.

Des Moines	Panama

Cucurbita Maxima

Group VII. Hubbard. The fruit is spherical in the middle, tapering to a curved neck at the stem end and to a somewhat curved point at the blossom end; shell very hard. Vegetatively homogenous. It should be noted that the Marblehead and Arikara are not so distinctively curved at the neck as the Hubbards, but otherwise fit well into the group.

Blue Hubbard	Kitchenette
Chicago Warted Hubbard	Marblehead
Golden Hubbard	Arikara
Green or Improved Hubbard	

Group VIII. Delicious. The members of this group are hard shelled and rather cone shaped, although differing in color.

Delicious	Pikes Peak	Winnebago

Group IX. Orange Marrows. These fruits are rather lemon shaped, ranging from light to reddish orange in color. Surface irregular.

Boston Marrow   Early Golden Marrow   Orange Marrow

Group X. Turban. The turban shape and button at the blossom end typify this group.

Essex Hybrid   Bay State   Am. Turban

Group XI. Banana. The outstanding points of the group are elongated fruit, somewhat pointed at both ends, soft shell and greenish gray color.

Banana   Plymouth Rock

Group XII. Pebbled. This group is marked by a deep orange colored skin, a very thick, hard and extremely pebbled shell.

Warren   Victor

Group XIII. Show or Display Group. This is a heterogenous combination of very large, soft shelled varieties, used chiefly for show purposes.

King of the Mammoths	Mammoth Whale
Mammoth Chili	Estampes
Atlas	

CUCURBITA MOSCHATA

Group XIV. Large Cheese. Although the members of this group are quite different in shape they are all marked by creamy buff color, smooth skin, thin hard shell and hard fruit stalk which flares conspicuously at the attachment to the fruit.

Large Cheese   Quaker Pie   French Cocoanut

Group XV. Cushaws. This group is marked by smooth soft-shelled fruits with long, curved necks.

Striped Cushaw	Mammoth Golden Cushaw
White Cushaw	Small Golden Cushaw

Group XVI. The distinguishing features of these varieties are the rather pear shaped fruit, smooth skin and the thick fruit stalk.

Japanese Pie   Tennessee Sweet Potato

Group XVII. Miscellaneous. The following varieties have not sufficient characteristics in common with others to warrant placing them in any particular group.

Winter Nut	Faxons Brazilian
Chirimen	Ironclad

Preliminary Notes on Tip-Burn of Lettuce

By R. A. McGinty and R. C. Thompson, *Colorado Agricultural College, Fort Collins, Col.*

Introduction

WITHIN the past 7 or 8 years the production of head lettuce in Colorado has increased from practically nothing to more than 3500 carloads annually. This rapid expansion of the industry has been accompanied by problems which inevitably occur under such circumstances.

One of these problems is tip-burn which has always been a factor wherever lettuce is grown. In Colorado, however, it seems to be of more serious import than in other lettuce-growing sections, both because of its prevalence and because heads affected with even a small amount of the trouble are unacceptable for shipment to the distant markets to which the product must go.

Lettuce tip-burn belongs to that large group of plant diseases classed as "physiological," and I presume needs no description here. Its seriousness with us is in the fact that the affected tissues offer easy entrance to various fungi and bacteria which may quickly ruin the plant either in the field or in transit.

A number of investigators have attacked the problem from various angles and several theories as to its cause have been advanced. These theories ascribe the trouble variously to fungi, excess light, improper fertilization, accumulation of salts at the margins of the leaves, etc. The most generally accepted idea, however, is that tip-burn is due to a high rate of transpiration which removes the water from the margin of the leaf more rapidly than it can be replaced, thus causing dessication of the tissues at that point.

As far as we have been able to determine, none of the work done on this problem has been conclusive, and we have, therefore, undertaken some experiments in an effort to throw more light on the subject.

It is the aim of these experiments to determine the effect of irrigation and of various fertilizers upon the occurrence of the disease, to make a study of temperature as a contributing factor, to develop, if possible, a tip-burn resistant strain of New York lettuce and to ascertain what relation, if any, the carbohydrates and other constituents have to the trouble. It is the purpose of this paper to present some preliminary data bearing mainly upon the last point.

Methods

The lettuce plants used in this work were grown on a solid bed in the greenhouse, usual methods of greenhouse culture being followed. The variety used was New York, since this is the variety exclusively planted for commercial growing in Colorado.

In our work with tip-burn we have made observations which point towards irrigation as a very important factor, so much so,

that other conditions being favorable, the disease may be brought on by applying water or prevented by withholding it.

To insure having both healthy plants and those affected with tip-burn, the plants in the bed were divided into 2 lots. One lot was watered sparingly and produced healthy heads. The other was watered generously (but not excessively) and produced plants, practically all of which showed tip-burn. Except for the amount of water applied, healthy and tip-burned plants had identical treatment. It might be expected, of course, that this difference in irrigation would bring about differences in dry matter and carbohydrate content without regard to tip-burn injury. Nevertheless, the figures indicate the conditions which prevail in plants resistant to, and susceptible to, the trouble. Plants were all harvested at 9 o'clock in the morning, carefully sampled and dried for 12 hours in a vacuum oven at 70° C. Harvesting of heads for analysis extended over a period of 3 weeks since they did not all mature at one time. In making the sugar analyses the very satisfactory method described by Spoehr was used. All determinations were made in triplicate and agreed closely.

Results and Discussion

Table I shows the results of the sugar analysis.

The striking fact regarding these figures is that the percentage of the different sugars is decidedly higher in healthy plants than in those affected by tip-burn They also show that there is a great deal of difference in the sugar content of individual plants of the same group, a greater difference than might be expected of plants growing under similar conditions. The percentage of dry matter found in the tip-burned plants is strikingly low, emphasizing the extreme succulence of such plants. The differences in sugar content and dry matter of the two groups have been subjected to statistical analysis and found to be significant.

Rosa, in his "Investigations on the Hardening Process in Vegetable Plants," reported a significant increase in the pentosan content when plants were subjected to hardening processes. He pointed out that the pentosans by increasing the water-retaining capacity of hardened plants make them more resistant to injury by freezing, which is primarily a matter of excessive water loss. He also suggested that since tip-burn of lettuce and potato plants is also considered to be due to excessive water loss, the trouble might be related to their pentosan content. In an effort to find if such relation exists a number of healthy and tip-burned lettuce plants were analyzed for pentosans. The results are shown in Table II, together with the corresponding dry matter determinations.

The figures for pentosans show a rather wide variation between individual plants of the same group, though no greater than have been reported by others. On a green weight basis, there is no difference in the pentosan content of healthy and diseased plants, while on a dry weight basis the greater percentage found in the tip-burned plants is of doubtful significance, since the difference is barely 3 times

TABLE I—SUGAR ANALYSIS OF HEALTHY AND TIP-BURNED LETTUCE PLANTS

Plant number	Percentage of the dry weight				Percentage of the green weight				Per cent dry matter
	Total sugars	Mono-saccharide	Disaccharides	Poly-saccharides	Total sugars	Mono-saccharides	Disaccharides	Poly-saccharides	
Healthy Plants									
6	13.400	6.716	3.626	3.068	1.015	.509	.274	.232	7.58
16	15.823	7.491	5.425	2.907	1.350	.630	.462	.248	8.53
18	19.116	6.858	8.124	4.134	1.556	.559	.662	.336	8.15
20	23.672	12.400	5.600	7.672	2.151	1.039	.469	.643	8.38
22	23.875	11.045	7.135	5.695	1.836	.865	.548	.438	7.68
31	22.474	11.120	6.755	4.600	1.689	.836	.508	.346	7.50
Average	20.060	9.271	6.111	4.679	1.599	.739	.487	.374	7.97
Tip-Burned Plants									
1	18.390	8.331	7.169	2.890	.943	.427	.367	.147	5.11
4	10.591	4.650	3.610	2.331	.500	.214	.170	.110	4.72
17	15.500	9.300	3.100	3.100	.852	.511	.170	.115	5.50
21	20.344	13.691	4.275	2.378	.912	.610	.193	.107	4.53
26	10.591	4.650	3.610	2.331	.500	.214	.170	.110	4.72
32	10.981	4.130	4.370	2.481	.612	.230	.243	.138	5.58
Average	14.222	7.269	4.292	2.493	.731	.376	.212	.120	5.22

TABLE II—PENTOSAN CONTENT OF LETTUCE WITH CORRESPONDING DRY WEIGHT

Plant number	Condition	Pentosan		Dry weight of plants
		Per cent of dry weight	Per cent of green weight	
5	Healthy	.439	.032	7.35
6	"	.742	.056	7.58
10	"	.881	.088	10.00
13	"	.768	.089	11.62
15	"	1.700	.110	6.50
16	"	.878	.075	8.53
18	"	.603	.048	8.15
19	"	2.250	.164	7.30
20	"	.824	.069	8.38
22	"	1.921	.147	7.68
35	"	1.097	.082	7.50
36	"	.714	.041	5.77
Average..		1.066	.083	8.03
1	Tip-burned	2.599	.132	5.11
21	"	.933	.042	4.53
26	"	2.250	.106	4.72
37	"	1.097	.053	4.80
38	"	1.100	.052	4.73
39	"	1.594	.097	6.05
40	"	1.921	.094	4.95
Average...		1.639	.086	4.98

the probable error. If the difference is significant, however, it is in favor of the tip-burned plants rather than the healthy ones as might have been expected. We found the pentosan content of these plants to be only one-fourth to one-half as great as that reported by Rosa for lettuce, and the amounts seem too small to affect the water content of the plants in any way.

In making the analyses for pentosan, we followed essentially the method used by Rosa with one exception. Rosa states that in separating the hexose and pentose sugars, he introduced a culture of yeast into the solution and allowed it to ferment *over night*. We found that all the hexoses were not removed from our solutions in this length of time, but that almost *36 hours* were required for eliminating them. This is in line with the procedure followed by Spoehr.

The dry matter determinations shown in Table II demonstrate in an even more striking manner than in the preceding table the greater succulence of the plants affected with tip-burn. In over 50 dry matter determinations made in the course of this work, the healthy plants have almost without exception possessed greater dry weight than the tip-burned plants.

In addition to the head lettuce plants for which figures have been given above, some plants of Grand Rapids, a variety of leaf lettuce, were dried in order to have a further check on this point. These plants were selected in pairs, consisting of one healthy and one tip-burned plant growing side by side under exactly similar conditions as far as could be observed. The results of these determinations are

given in Table III, which again shows the healthy plants to have the greater dry weight.

TABLE III—DRY MATTER OF HEALTHY AND TIP-BURNED GRAND RAPIDS LETTUCE PLANTS

Plant number	Condition of plant	Per cent of dry matter
1	Healthy	5.77
1a	Tip-burned	4.95
2	Healthy	5.74
2a	Tip-burned	5.16
3	Healthy	5.53
3a	Tip-burned	4.67
4	Healthy	5.03
4a	Tip-burned	4.51

Average Dry Weight of Healthy Plants 5.51
Average Dry Weight of Tip-Burned Plants 4.82

From the data in Tables I, II, and III on carbohydrate and dry matter content, it appears that tip-burn is significantly related to these factors. Where there is abundant soil moisture which provides the conditions for the development of plants with high water content, the disease is at its worst, while with the minimum soil moisture content sufficient to grow lettuce the plants remain healthy; also, diseased plants may recover if the proper soil moisture conditions can be provided.

Temperature and relative humidity seem to be much less important factors. In the greenhouse the development of tip-burn occurs and healthy plants grow at the same temperature and relative humidity, the presence or absence of the disease being dependent, apparently, upon soil moisture. In the field we have observed a number of times that when the soil moisture is properly adjusted, the disease does not occur during a period of hot weather, even though the plants wilt in the middle of the day due to high transpiration, while it will develop rapidly during cool rainy weather when the soil moisture and presumably the relative humidity are high. Temperature is, however, of some importance, since, other factors being equal, the disease is more serious during periods of high temperature. It has been found by Newhall that the temperature of the lettuce plant is considerably higher than that of the surrounding air, and this may have some bearing upon the greater injury which occurs during periods of high temperature. It seems doubtful, however, if the temperature of the lettuce plant is ever high enough to cause direct injury.

As stated above excessive transpiration is commonly ascribed as the cause of tip-burn. The higher water content of the diseased plants would seem to contradict this theory to some extent. As further evidence on this point, we cite the results of a simple experiment in which 10 healthy lettuce plants of New York were grown under large bell jars, 1 plant to each jar. An opening in the top of the jars allowed some circulation of air, but a humid atmosphere was provided as indicated by the condensation of moisture on the sides of the jar. After being under the bell jars for 2 weeks, 6 of the 10

plants developed typical tip-burn injury. Since transpiration could not have been excessive in the humid atmosphere provided, some other factor must have been responsible in this case.

In these experiments, tip-burn could be controlled to a great extent by withholding water, especially as the plants neared maturity. This method of control may be used in the field where lettuce is grown under irrigation, provided rains do not occur.

Summary

In the greenhouse-grown lettuce plants used in these experiments, the monosaccharides, disaccharides and polysaccharides are all significantly higher in healthy than in tip-burned plants.

There seems to be no significant difference in the pentosan content of healthy plants as compared with those affected with tip-burn.

It is doubtful if the amount of pentosan present in lettuce plants is sufficient to affect the water retaining capacity of the plant.

Almost without exception, the percentage of dry matter in tip-burned plants grown in the greenhouse has been found to be less than that of healthy plants.

Abundant soil moisture and a high water content in the plants are both favorable for the development of tip-burn.

Field observations indicate the following: High temperatures encourage but do not cause tip-burn. Tip-burn may occur when the relative humidity is high and transpiration is below normal. The disease is not due to excessive water loss caused by a high transpiration rate.

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Physical and Chemical Changes in Celery During Storage*

By L. W. Corbett, *West Grove, Pa.*, and H. C. Thompson, *Cornell University, Ithaca, N. Y.*

THE studies reported in this paper represent certain phases of a general study of celery storage which has been carried on intermittently by one of the writers (Thompson) for several years. In the early work no attempt was made to determine the changes which

*The microchemical studies were made by Thompson under the guidance and direction of Dr. H. C. Sampson of the Department of Botany, Ohio State University, in the fall of 1923. The physical and chemical studies were made by Corbett in 1924–25 and the results submitted as a Master's Thesis in Cornell University, June, 1925.

take place in the plants themselves, but rather to record the observed effects of various environmental factors on the keeping of the product. It has been thought that a study of the physical and chemical changes taking place in celery during the storage period might lead to a better understanding of the factors involved. With this idea in mind the writers undertook the studies here reported.

Microchemical Studies

Microchemical studies were undertaken primarily to determine, if possible, the changes which take place in the cellwall materials during storage. Some studies were also made on the materials in the cell, especially on sugars, proteins, amino acids and nitrates, but without any significant results.

The celery used in this work was Golden Self Blanching grown at Williamson, New York, in connection with a fertilizer experiment, which had been under way for 4 years. At harvest time, October 22, 1923, samples were taken from plats which had received different fertilizer treatments and these were shipped by express to Columbus, Ohio. On arrival October 24, they were placed in cold storage. Samples from 2 fertilizer treatments, 1 with high nitrogen alone, the other with high phosphorus and high potash, but no nitrogen, were taken at intervals of 1 week from October 31 to December 6. Microchemical tests were made on sections of the leaf stalks, care being taken to get representative and comparable samples. The tests used were those outlined by Eckerson. (Microchemistry unpublished laboratory outlines).

Pectic Compounds

Of the various substances, for which tests were made, the pectic compounds of the middle lamella gave the most significant results. Ruthenium red was used as stain and 2 per cent KOH, 5 per cent oxalic acid, and 2 per cent HCL were used for solubility tests in determining the types of pectic compounds present in the cells of the leaf stalk at various times during storage. Polarized light was also used to detect the presence or absence of pectic substances in the cell wall. The terms used in this paper to designate the different pectic compounds are those employed by Eckerson.

Tests made on the samples of celery from the high nitrogen plats at the end of the first week in storage showed very little water soluble pectin, but considerable material soluble in 2 per cent KOH, (pectic acid), and still more soluble in 5 per cent oxalic acid, (calcium pectate). After treating the sections with 5 per cent oxalic acid, followed by 2 per cent KOH and water, so little of the pectic layer was left that the cells began to separate. This indicates that very little pectose was present. Oxalic acid breaks down calcium pectate into pectic acid and calcium oxalate, crystals of the latter being plentiful after the treatment.

Tests made at the end of the second week gave results similar to those made the previous week. At the end of the third week there

was a marked increase in the more readily soluble pectic compounds, pectin and pectic acid, and a decrease in calcium pectate and pectose.

During the fourth, fifth and sixth weeks there was a gradual increase in the more readily soluble pectic compounds and a decrease in the less soluble compounds. By the end of the sixth week practically all of the pectic layer disappeared on treatment with 2 per cent KOH and washing with distilled water. After these treatments the cells began to separate, indicating a change from calcium pectate and pectose to pectic acid and pectin. Another indication of change in the pectic compounds is shown by the copper-oxide-ammonia treatment used for dissolving cellulose. During the first few weeks sections given this treatment remained intact after the cellulose was dissolved, but later this treatment for 24 to 48 hours resulted in disintegration of the sections, due to separation of the cells. In other words, the pectic compounds gradually changed to forms soluble in this solution. There was also a decrease in the resistance of the cellulose during storage, but efforts to determine the changes in the form were not successful.

Tests were also made on celery plants grown with fertilizer high in phosphorus and potash, and these showed the same changes in the pectic compounds as was shown in the plants grown on plats fertilized with nitrogen alone. However, the rate of change was much slower in the celery grown under the phosphorus-potash treatment than in that from the nitrogen plat. In fact, the celery from the nitrogen plat had reached in 4 weeks practically the same stage that the plants from the phosphorus-potash plat had reached 2 weeks later. This was shown by the changes in the pectic layer and also by the general appearance of the celery. At the end of 4 weeks, in the celery from the nitrogen treatment, and at the end of 6 weeks in the other lot, blanching was complete and decomposition had set in. This stage was reached several weeks earlier than is expected under good cold storage conditions, due to relatively high temperature, 35° to 40° F. Thompson (U. S. D. A. Bull. 579) has shown that a rise of a few degrees (from 32° to 35° F. for example) materially hastens maturity and subsequent decomposition, and, therefore, shortens the storage life of the product.

In the storage experiments during the preceding 3 years it was found that the celery from the plats fertilized with nitrogenous fertilizers only did not keep as long as that from the complete fertilizer plats, or that from the phosphorus-potash treatment. The microchemical tests showed a very close correlation between the breaking down of the middle lamella and the observed changes in the celery stalks themselves. The explanation and significance of this correlation is a matter of speculation. It seems possible that the change from calcium pectate and pectose to pectic acid and pectin might have some effect on the entrance of organisms responsible for decomposition. How the fertilizer nutrients affect the cell wall materials is not clear. It was noted, however, that the cell walls were thinner in the celery from the high nitrogen plat than in that from the phosphorus-potash plat.

Physical and Chemical Studies

The celery used in these studies was grown at Williamson, New York, in connection with fertilizer experiments already mentioned. The crop was harvested September 19, 1924, and the experimental material was hauled to Ithaca and placed in cold storage. The celery was soft and in rather poor condition for storage, due to rapid growth and early maturity. The poor condition of the product at harvest time and the relatively high and fluctuating temperature, (32–40° F.), maintained in the storage room made long keeping impossible. It is believed, however, that the changes noted are those that normally take place, but undoubtedly the rate of change was higher than would be found under ideal storage conditions. Observations made on some of this celery, which was removed from cold storage and trenched, show that the same changes took place under the two conditions, but that the rate of change was very different. The changes took place at a much more rapid rate in the trenched celery, where the temperature was relatively high, than in the cold-storage room.

Physical Tests

Two types of physical tests were employed. One was a breaking test in which the weight necessary to break sections of the leaf stalks one-half inch in diameter, with a given leverage, was recorded. The other was a cutting test, in which a fine wire was used and the weight necessary to force the wire through stalks five-eighths of an inch in diameter was used as the measure. These tests were made on 16 stalks at weekly intervals. Due to the difficulty of getting uniform samples for the test the error was large and the results not conclusive. They indicate, however, a rather sudden decrease in resistance as measured by the weight necessary to break or cut the stalk, during the first week or 10 days in storage. This was followed by little change for the next few weeks and finally by a sharp decrease in resistance toward the end of storage. These changes coincided with the changes observed in the cell walls.

Examination of the celery at intervals of a week showed the following changes in appearance of the product: First, the leaves lost their green color and took on a yellowish hue, followed by a brownish discoloration before decay actually set in. These changes did not take place uniformly throughout the crate, the outside and top leaves changing first. The outside stalks of the plants were next to show changes; the greenish-white changed to white, then to a straw color and this was followed by a water-soaked appearance. Soft rot was evident very soon after the change to the water-soaked appearance. The inner or heart stalks were the last to show the changes mentioned.

The heart stalks increased in length while in storage. This was very noticeable in the trench, but also took place in the cold storage room. The food for this growth probably came from the other portions of the plant—the leaves, the outside stalks, and the stump or base of the plant. Chemical analyses showed translocation of food

material from the leaves to the stalks and from outside to inside stalks.

Chemical Analyses

The material for analysis was carefully selected from several plants in order to secure uniform and representative samples. These were divided into 3 parts, (1) outside leaf stems, (2) inside leaf stems or hearts and (3) leaves. One hundred gram samples were taken and the material was cut into small pieces. Sufficient 95 per cent alcohol was used for preservation to make the final concentration 80 per cent. One-half gram of calcium carbonate was added to neutralize any acid that might be present. The alcohol was brought to a boil and the samples dropped into it and again heated to boiling on the water bath. The jars containing the samples were then sealed and held for several weeks. The material was then ground and extracted with hot 80 per cent alcohol, 5 extractions being made on each sample. After extraction, the residue was dried in an oven, allowed to cool, and ground very fine and saved for determination of insoluble nitrogen. The alcoholic extract was filtered into liter flasks and brought up to mark with 80 per cent alcohol.

Sugars.—In the determination of sugars, 300 cc. of the alcoholic extract was evaporated down to about 10 cc. on a water bath, and this was diluted with distilled water to make 100 cc. Neutral lead acetate was used for clearing and excess lead was removed by potassium oxalate. The deleaded solution was filtered into 250 cc. flasks and brought up to the mark (at 20° C.) with distilled water. Reducing substances were determined from duplicate 50 cc. aliquots of this solution, using Fehling solution and heating method recommended by Quisumbing and Thomas (Jour. Am. Chem. Soc. 43. 1520–1921). For determining total sugars 10 cc. of concentrated HCl were added to the 100 cc. solution remaining in the flask and this was allowed to stand for 24 hours at 20° C. After neutralizing with NaOh, the solution was brought up to 200 cc. and the procedure given above was followed. For determining the copper reduced the gravimetric method was employed.

Table I gives the results of the sugar analyses of samples of celery taken a week before harvest, at harvest, and at 6 different times during storage.

Examination of Table I shows that there was a marked increase in reducing sugars in all parts of the plant during the week preceding harvest. During this period the temperature was relatively low, too low for much growth, and accumulation of sugars would be expected. At harvest time the leaves and outside stalks contained practically the same percentage of reducing sugars. From this time on the reducing sugars and total sugars increased in both the inside and outside stalks until a maximum was reached, and after this there was a marked decrease. In the leaves both reducing and total sugars show a marked reduction from harvest time to the end of the storage period. The decrease in sugars in the leaves probably is due mainly to translocation to the stalks. Respiration accounts for some

loss of sugar in the leaves, but this would be partially, if not entirely, offset by loss of water. Increase in sugars in the stalks may be accounted for by hydrolysis of polysaccharides, by translocation from the leaves and by loss of water. The marked decrease in sugars toward the end of the storage period was accompanied by decay, and it seems probable that the decay organisms were responsible for this decrease.

TABLE I—REDUCING SUGARS AND TOTAL SUGARS IN CELERY LEAVES AND STALKS

Date	Grams reducing sugars in 100 gram samples			Grams of total sugars in 100 gram samples		
	Inside stalks	Outside stalks	Leaves	Inside stalks	Outside stalks	Leaves
September 12	.3578	.04556	.1257	—	—	—
September 19	.8005	.35107	.3587	.8446	.56004	.9866
September 30	.7181	.44680	.2073	1.4620	.8520	.7411
October 15	1.0990	.79536	.1823	1.7234	1.0326	.3224
October 29	1.2855	.83760	.1417	2.2810	1.1511	.265
November 12	.8780	.92664	.0320	2.0118	1.3353	†.0472
November 20	.770	.755	—	1.8808	1.1836	—
—	—	*0.0757	—	—	*.0776	—

*Outside non-edible stalks.
†.Yellow leaves.

Nitrogen.—Soluble nitrogen, including nitrates, was determined in duplicate 150 cc. aliquots of the alcoholic extract as follows: The extract was pipetted into 650 cc. Kjeldahl flasks, evaporated nearly to dryness and distilled water added to bring the volume up to about 100 cc. To this was added one-half gram of Devarda's alloy, a small piece of paraffin and 10 cc. of N. NaOh. The flasks were connected to the distilling apparatus and the solution was distilled for 30 minutes into 20 cc. .2N HCl, using methyl red as indicator. The flasks were cooled and the contents digested. After digestion and dilution, the solution was made alkaline and distilled briskly for about an hour, distilling into the same acid solution used in the first distillation. Insoluble nitrogen was determined, by the Kjeldahl method, using .7 gram of the ground residue. Table II gives the results of the nitrogen determinations.

TABLE II—SOLUBLE AND INSOLUBLE NITROGEN IN CELERY LEAVES AND STALKS AT INTERVALS DURING STORAGE

Date	Mgs. of soluble nitrogen in 100 gram samples			Insoluble nitrogen, mgs. in 100 gram sample		
	Inside stalks	Outside stalks	Leaves	Inside stalks	Outside stalks	Leaves
September 19	17.03	12.36	27.99	30.80	68.78	298.20
September 30	—	20.53	88.43	32.10	—	282.50
October 15	141.29	46.19	99.62	83.77	36.17	233.05
October 29	194.35	78.34	163.79	111.67	43.41	281.30
November 12	160.99	101.02	67.19	138.64	53.41	rot
November 20	170.79	83.99	rot	121.12	40.26	rot
—	—	—	—	—	*25.27	†171.76

*—Outside non-edible.
†—Yellow leaves.

Study of Table II shows a marked increase in soluble nitrogen in the leaves from harvest time until October 29, after which there was a decrease from 163.79 mgs. to 67.19 mgs. In the outside stalks the soluble nitrogen increased from 12.36 mgs. at harvest time to 101.02 mgs. on November 12, after which there was a decrease. The inside stalks showed a ten-fold increase from harvest time to October 29, after which there was a decrease. From October 15 to the end of the season the inside stalks contained considerably more soluble nitrogen than either the outside stalks or leaves.

Insoluble nitrogen, in general, decreased in the leaves and increased in the inside stalks. The exception shown in the table is due probably to faulty sampling, as the yellow leaves showed a marked decrease. There was also a decrease in insoluble nitrogen in the outside stalks from harvest time to October 15, after which time there was a slight increase. This small increase might have been due to loss of water. The leaves contained much more insoluble nitrogen than the stalks, and the inside stalks much more than the outside stalks after the first few weeks.

Both soluble and insoluble nitrogen increased in the stalks up to a maximum and then there was a decrease. The decrease began about the time the tissues started to break down.

Summary

Microchemical tests made on celery stalks at weekly intervals during storage, indicate a marked change in the pectic compounds of the middle lamella. The more resistant compounds, calcium pectate and pectose, changed to the less resistant pectic acid and pectin. These changes took place more rapidly in celery grown on plats fertilized with nitrogenous fertilizers alone than in celery grown on the phosphorus-potash plats.

There was a close correlation between the changes in the pectic compounds and the observed changes in the celery.

Physical tests made at intervals of 1 week showed a marked decrease in resistance during the first week or 10 days in storage. This was followed by little change during the next few weeks and finally, by a sharp decrease in resistance toward the end of the storage period.

Chemical analyses of different parts of the plants showed marked changes in reducing and total sugars and also in both soluble and insoluble nitrogen. Both reducing and total sugars in the leaves showed a marked decline from harvest time to the end of storage. In both outside and inside stalks reducing and total sugars increased until toward the end of storage when there was a sharp decline. The decrease in sugars in the leaves probably was due mainly to translocation to the stalks.

Soluble nitrogen increased in both the leaves and stalks from harvest time until toward the end of the storage period when there was a very marked decrease in the leaves, and a slight decrease in the stalks.

Insoluble nitrogen was high in the leaves at harvest and in general decreased from that time to the end of storage. In the outside

stalks the insoluble nitrogen decreased during the first month and for the next few weeks there was little change, followed by a sharp decline about the time decay set in. Insoluble nitrogen increased in the inside stalks from harvest time until toward the end of storage, after which there was a decrease. It seems probable that the increase of insoluble nitrogen in the inside stalks resulted from translocation from the leaves and outside stalks. Of course translocation must have been preceded by change from insoluble to soluble forms of nitrogen.

Studies Dealing with the Lying of Corn and the Varieties Best Adapted for Hominy Making

By E. S. HABER, *Iowa State College, Ames, Iowa.*

THIS problem was suggested by some of the hominy packers in the State of Iowa who were experiencing more or less difficulty in maintaining a uniform pack and were not always able to account for the variation in quality. The work was started in the fall of 1920 and most of it completed in 1922.

The factors which determine the value of a given variety of corn for hominy purposes are: first, readiness with which the cap or tip (the pedicel of the kernel) can be removed; second, maximum swelling of the grain; and third, the color of the finished product. For this reason the following points were studied: adaptability of various varieties, the amount of swell, temperature and time relation in lying, strength of lye solution, moisture content, age relation, absorption during the lying process, etc.

A number of tests were made of each variety using the following procedure. The corn was treated with a 2 per cent lye solution kept at 90° C. while constantly stirred. This process continued until the tips of the kernels could be brushed off easily. Then a total of 2½ hours boiling was given at the following intervals to remove the lye and to obtain as much of the "swell" or increase in volume as possible.

Boiled 10 minutes and water changed.
" 10 " " " "
" 25 " " " "
" 35 " " " "
" 70 " " " "

Then six-tenths of a gram of sodium bisulphite to each pound of corn was added and the corn covered with water and boiled from 15 to 20 minutes to bleach the corn. Then the corn was boiled in 3 changes of water at 10 minute intervals to remove the sodium bisulphite. The hominy was then placed in Number 2 cans, sealed and processed for 70 minutes at 242° C.

Tests for amount of swell were made by counting the number of

grains of dry corn required to fill a Number 2 can and then the number of grains of hominy filling the can was counted and percentage of increase determined.

Where moisture content of the corn was found, the Brown-Duvel moisture tester was used. This was thought to be sufficiently accurate for this purpose and saved much time over the oven drying and weighing method. From 6 to 8 hours were required for each determination. When the test was once started, the process was continued until finished and not allowed to stand, so as to follow factory conditions and methods as far as possible.

For all determinations enameled containers or glassware was used because Bigelow (3) found that black discoloration in hominy was due to iron sulfide which was formed when iron was present because hydrogen sulfide is liberated during processing.

Table I gives the results of the tests of the varieties.

TABLE I—RESULTS OF TESTS OF DIFFERENT VARIETIES

Variety	Type of kernel	Moisture content per cent	Lying period required minutes	Per cent swell	Condition of finished product
Silver King	Narrow	14.5	35	316	Grains broken up, grayish in color
Boone County White	Narrow	12.0	35–40	315	Grains whole, white
Hickory King	Broad	11.5	25	360	Grains whole, white, larger than any variety tested
Commercial White	Broad	12.0	30	348	Grains whole, white; nearly as large as Hickory King
White Elephant	Broad	12.2	25–30	412	Grains whole, white and about as large as Hickory King
St. Charles	Narrow	11.2	35–40	297	Grains whole, white, attractive, but small
*Corn Planter	Broad	11.8	40	327	Grains whole varying in size from large to small. Some grains lye burnt
Silvermine	Narrow	11.7	40	312	Grains whole, not very large; slightly lye burnt
White Pearl Flint	More or less spherical	10.8	40	355	Grains whole, grayish in color with more of pericarp remaining on kernels than in dent varieties
Yellow Dent	Narrow	11.3	35–40	—	Grains whole but unattractive; light yellow color
Evergreen Sweet Corn	Narrow	15.2	60	—	Kernels soft, broken, endosperm yellow, germ grayish; liquor very roily

*Many narrow kernels present.

OLD AND NEW CORN COMPARED

Two varieties, Hickory King and Silver King were used to determine if there were any differences due to the age of the corn.

Samples of the new crop and the crop of the preceding year were used and all samples contained the same moisture content so this would not cause a variation. The old lots of corn of the same variety required at least 5 minutes more lying in order to remove the tips than the new corn.

The Effect of Increasing or Decreasing the Strength of the Lye Solution

In all the investigations so far, a 2 per cent lye solution was used because this is the one commonly used by canners. This test was run to determine if a stronger or weaker solution would give better results. Boone County White was used with a moisture content of 12 per cent so the condition of the corn would be the same for all.

Two per cent Solution—Lying required about 40 minutes and the finished product was fair.

One per cent Solution—Lying was continued for 75 minutes, but still the tips could not be removed. The corn was swelling and becoming soft and broke up when brushed vigorously to remove tips.

Three per cent Solution—Lying required 30 minutes, but the finished product was lye burnt and so rendered unattractive.

Four per cent Solution—Lying required 22 minutes, but the hominy was very badly discolored because of lye burning.

From the above results it can be seen that attempting to decrease the length of lying period by an increase of the lye concentration hastens the lying period, but the lye penetration is greater causing lye-burning so nothing is gained. A weaker solution is not satisfactory and 2 per cent appears to be the optimum.

Bleaching the Hominy Before Canning

Corn bleached this way is a purer white than corn which is not bleached. Sodium bisulphite, 0.6 gm. to each pound of corn, is used after the lye has been removed by boiling. The sodium bisulphite was removed by boiling in 3 changes of water at 10 minute intervals. Cans which were sealed without bleaching, were opened 6 months later and compared with the same variety of corn which had been bleached and it was found that black discoloration due probably, as Bigelow (3) states, to iron sulphide, was far less pronounced in the bleached product. The bleached corn was not entirely free from this black discoloration, but at least very much improved.

Lying Affected by Moisture Content of Corn

Commercial White corn was used for this

Lot number	Moisture content per cent	Lying period minutes
1	3.2	40
2	5.8	40
3	6.9	35–40
4	7.8	35
5	10.0	30
6	12.0	30
7	16.0	25–30
8	23.3	20–22

Five lots of Hickory King with varying moisture content were tested in the same way.

Lot number	Moisture content per cent	Lying period minutes
1	7.5	25–30
2	9.5	25
3	13.0	25
4	15.5	20–25
5	18.0	20–25

With a higher moisture content, the tips and hull can be removed with a shorter lying period, but the finished product is not so attractive because the grains are broken up and the product less attractive. Too low moisture content requires a longer lying period to remove the tip, but the hull dissolves faster, though not as fast as at the higher moisture content. Usually lye burning is apt to result if the moisture content is too low. From 10–15 per cent moisture seems to be most satisfactory.

Time Required to Remove Lye

Hickory King was used to determine the length of time and changes of water necessary to remove the lye before putting it in the cans. In the following table the water was drained off after each boiling period and this tested for lye by titrating 25 cc. of this against N/50 sulfuric acid using phenolthalien as an indicator.

Length of the boiling-period, minutes	Per cent of lye in solution after boiling
10	0.59
10	0.14
25	0.07
35	0.04
70	0.029
*30	0.0076

*An extra 30 minute boil more than the usual process was given.

The next determinations were made with 2 lots of St. Charles corn with widely different moisture contents.

Lot number 1—Moisture content 8.6 per cent—lyed in 38 minutes.

Length of boiling-period, minutes	Per cent of lye in solution
10	0.46
10	0.102
25	0.047
35	0.036
70	0.027

Lot number 2—Moisture content 18.8 per cent—lyed in 25 minutes.

Length of boiling period, minutes	Per cent of lye in solution
10	0.40
10	0.074
25	0.031
35	Just a faint trace of color when phenolthalien was added

It requires less time to remove the lye where the corn has a higher moisture content because the lying period is shorter. However, too high a moisture content causes the kernels to break up more readily.

The Effect of Mixed Corn on the Finished Product

One sample of Boone County White tested was badly mixed. Some of the kernels showed the effects of crossing with a yellow variety. After lying for 35 minutes it was comparatively easy to remove the tips from most of the grains, but with 10 or 15 per cent, the tips clung tenaciously. The kernels in the finished product varied in color having white, gray, and several shades of yellow kernels which presented an unfavorable appearance.

Effect of Grading Corn

Although the Corn Planter variety is a broad-kerneled type, more often it is found to have many narrow kernels present. Narrow kernels were found in any of the broad types of corn. Even in the varieties with narrow type kernels we find a variation between the kernels which come from the tip and butt of the ear as compared to the rest of the kernels. This variation in size is often the cause for variation in lying. A sample of the Corn Planter was graded so that the narrow kernels were removed. Instead of 40 minutes usually required for lying, the time could be cut down to 30 minutes with a better finished product as the result. Grading adds more cost to the canner so it is probably better to buy corn which is as nearly uniform as possible rather than resorting to grading.

Temperature During Lying Process

Marden and Montgomery (6) found 70° C. a convenient temperature for lying, while the writer in his investigations found it more convenient to keep the solution at an incipient boiling. No doubt the canners of hominy would find incipient boiling a convenient temperature. This, when measured with a thermometer, was found to range from 87° to 92° C. The hulling can be completed in about two-thirds of the time when the solution is kept at an incipient boiling rather than at 70° C. This lead up to the following experiments to determine what effect temperature had on the absorption which would give some indication of the penetration of the lye.

Absorption During the Lying Process

The rate of absorption at 100° C. was compared between 2 per cent lye solutions and distilled water solutions, at 5 minute intervals for 45 minutes. A 45 minute period was used because it requires from 20 to 45 minutes to lye corn in the process of making hominy.

The following was the procedure in all cases: Ten whole kernels of corn with the pericarp and germ uninjured or broken in any way, were used in each sample. Rose (7) found increased and quicker germination of seeds by puncturing the seed coat, due no doubt to some extent to the increase in rate of absorption, so in selecting the 10

kernels broken or injured grains were discarded. No attention was paid to germination to determine if the seeds were alive or dead, since Atkins (1) found that the absorption of water by living and dead seeds was identical until germination commenced.

After weighing, the grains were placed in a test tube and the test tube filled about two-thirds full of solution, with checks kept on all tubes. These were placed in an oven regulated to the desired temperature. When the corn had soaked the required time, the tubes were removed from the oven about 1 minute before the time was reached, the water drained off and the corn blotted between filter papers to blot off any excess surface moisture. The corn was then weighed in a weighing bottle and the increase in weight due to absorption determined. This was the method used by Bakke and Plagge (2) in the determination of moisture absorbed by wheat.

Corn in Water at 100°C.

Sample number	Time minutes	Weight of dry corn	Soaked	Increase	Per cent increase
1	5	3.8689	4.1487	.2798	7.23
2	10	4.0419	4.4607	.4188	10.36
3	15	3.6391	4.1242	.4851	13.33
4	20	3.7762	4.447	.6685	17.70
5	25	3.9750	4.7765	.8015	20.18
6	30	3.9092	4.780	.8708	22.27
7	35	3.9136	4.7766	.8603	21.98
8	40	4.1366	5.0579	.9213	22.28
9	45	4.0113	4.9139	.9026	22.50
		Corn in Lye at 100°C.			
10	5	4.1035	5.0986	.9951	24.25
11	10	4.0731	5.1524	1.0793	26.51
12	15	3.9637	5.0352	1.0715	27.23
13	20	4.0991	5.4151	1.3160	32.14
14	25	3.8073	5.2719	1.4646	38.46
15	30	4.1343	5.7615	1.6272	39.35
16	35	3.2820	4.8422	1.5602	47.23
17	40	3.7444	5.5079	1.7635	47.09
18	45	3.7354	5.6335	1.8981	50.81

During the first 5 minute interval the increase in weight due to absorption was much greater in lye solution than in the water solution, a difference of 17.02 per cent in favor of the lye solution. At the end of the 45 minute period, there was a difference of 38.31 per cent in favor of the lye solution. The curve representing the absorption of the corn in the water is more regular than the curve representing the lye solution, but this does not always hold true as we will see in examining the results obtained at other determinations.

We would expect greater absorption in the lye solution since Fisher (4) found that simple proteins in the presence of acids of alkalis had their absorbing power greatly increased. However, this difference in favor of the lye solution is also due in part to the dissolving of the pericarp by the lye which would increase the rate of absorption.

Summary and Conclusions

1. White dent corn with a broad type of kernel makes the most satisfactory hominy because of the more attractive finished product and greater percentage of swell. The broad types require less time for l ing if other conditions such as moisture, age of corn, etc., are equal.

2. A 2 per cent lye solution is the most satisfactory. Higher concentrations cause lye burning and weaker solutions require too much time.

3. Mixed corn cannot be used. It must be 100 per cent white. Even a very small percentage of yellow grains renders the finished product unattractive.

4. Corn of a uniform size should be used to secure an even lying process to all kernels. Kernels from the butts and tips are usually off-shape or type and if possible should be discarded.

5. New corn is more satisfactory than old corn because it does not require as long a l ing period.

6. Bleaching with sodium bisulphite before processing makes a purer white hominy and to some extent prevents black discoloration.

7. Moisture content affects the lying process. The lying process decreases as the moisture content of the corn increases. Corn with too high a moisture content breaks up too readily in processing. Too low moisture content requires too long to lye with consequent lye burning of the starchy portion of the kernel.

8. The length of time of boiling to remove the lye is proportional to the time exposed to the lye as well as influenced by moisture content. Corn l ed a short period absorbs less lye than one lyed a greater length of time if the moisture content and age of the corn are the same for both.

9. Incipient boiling is a convenient temperature for lying and hastens the process, cutting off about two-thirds of the time compared with 70° C. boiling.

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Some Effects of Fertilizers on Sweet Potatoes

By J. T. QUINN, *University of Missouri, Columbia, Mo.*

THE Department of Horticulture of the Missouri Agricultural Experiment Station has been conducting fertilizer experiments with sweet potatoes for the last 5 years with the object of determining whether the increase in yield from the use of commercial fertilizers would justify their use, on a commercial scale.

In 1923, some work was started in regard to the storage of sweet potatoes. The outline of this problem necessitated the making of carbohydrate analyses of the sweet potato roots at different periods of their growth. While making these analyses it was noted that samples taken from certain plots were uniformaly higher in starches and sugars than were the other samples. On investigation it was found that these sweet potatoes were from plots which had been fertilized with quite heavy applications of muriate of potash. Although, our fertilizer experiments were not outlined with the intention of determining the effect of fertilizers on the carbohydrate content of the sweet potàto, nevertheless, that same year (1923) samples were taken from plots representing as nearly as possible the different fertilizer elements, alone and in combination.

This work was conducted on a Putnam silt loam, a type of soil prevailing throughout the eastern part of North Missouri. Although not the best type of soil for sweet potatoes, it produces good yields during average years. The plots were one-fortieth of an acre in size and were all run in duplicate. The Porto Rico variety of sweet potato was used. The potatoes were planted by the ridge method, the fertilizer being applied in the row and mixed with the soil after the ridges had been formed.

METHODS

To make the sampling as accurate as possible 50 potatoes from each plot were used. Small amounts were taken from each root to make approximately 350 grams. This material was forced through a sampling press, after which the pulp was placed in 1 liter flasks and covered with 95 per cent alcohol.

Sugar and starch analyses were made, the thiosulphate method being used for the sugar determination while the diastase method was used for the starch determination.

In the accompanying table 2 years' data are presented on the effect of different fertilizers on the total yields, yields of marketable potatoes, and percentages of starch and sugar. These data show that although the total yields are very little affected by the fertilizer treatments, the percentages of marketable potatoes were increased where fertilizers containing potash were used. In fact, with the exception of bone meal in 1924, the only plots to yield more marketable potatoes than the check plots were those having potash, alone or in combination. In 1923, barnyard manure gave the lowest yield of

marketable potatoes, while sodium nitrate gave the lowest yield in 1924, followed closely by manure and dried blood.

Careful observations throughout both seasons did not show any effect of the fertilizers upon the amount of growth or general condition of the potato vines.

Of the many investigators who have made carbohydrate analyses of the sweet potato for different purposes, Shiver (1) was among the first to note that the composition of the sweet potato was affected by fertilizers. Other investigators as Stoklasa (2) have shown that potassium has much to do with carbohydrate formation in plants.

The data here presented show that there is a very definite correlation between the use of potash fertilizer and the percentage of carbohydrates. This is especially true with the starches, which are highest where potash was used and which increase with the amount of potash applied. The percentages of sugars were also higher where the potash fertilizers were used, with the exception of acid phosphate, which gave a small increase over the potash used in a mixed fertilizer. In 1923, all of the fertilizer treatments with the exception of nitrate of soda and manure, had a higher percentage of starch than the checks In 1924, all treated plots gave a higher percentage of starch than the checks. In 1923, all treated plots showed an increase in percentage of sugars, while all but nitrate of soda and manure showed an increase for 1924.

Schermerhorn (3) has shown that the sweet potato root is influenced by the kind and amount of fertilizer used. He presented data to show "that as the potash decreased, the yield of marketable tubers decreased, and vice versa, as the potash is increased up to 8 per cent, there is a decided increase in yield." He also gave data and illustrations to show that by using different percentages of potash the form of the potato roots were effected. Where no potash was used, the roots measured 6.98 inches in length and 1.66 inches in diameter, where 8 per cent of potash in a mixed fertilizer was used the roots measured 5.40 inches in length and 2.19 inches in diameter. Observations at the Missouri Experiment Station have shown the form of at least 2 varieties of sweet potatoes, the Nancy Hall and Porto Rico, to be greatly influenced by potash fertilizers. This was especially true of the Porto Rico variety, which produced a more blocky uniform potato where potash was applied.

Shiver has shown a relation between potash and carbohydrates. Schermerhorn has shown a relation between potash and form. Since yield of marketable potatoes depends primarily on blockiness of form, the data presented in this paper show a definite relationship between form and carbohydrates in the sweet potato.

The effect of potash fertilizers on form would, therefore, seem to be more directly associated with the well established relation between potash and carbohydrate manufacture. It is well known that the wrinkled varieties of the pea are sweet and round varieties are starchy and a similar relation between form and chemical composition apparently holds for the sweet potato where high carbohydrate and particularly high starch is correlated with fullness of form.

EFFECTS OF DIFFERENT FERTILIZERS ON YIELD, AND CARBOHYDRATE CONTENT OF THE SWEET POTATO

	Yield in bushels per acre				Starch Per cent of dry weight		Total sugar Per cent of dry weight	
	1923		1924					
	Total yield	Yield marketable potatoes	Total yield	Yield marketable potatoes	1923	1924	1923	1924
No treatment	167.4	155	148.2	126	56.79	53.11	14.76	15.44
Muriate of potash, 200 pounds per acre	171.2	162	152.0	138	68.26	65.72	18.42	17.93
Acid phosphate, 200 pounds per acre	168.0	151	150.3	122	61.32	55.80	17.18	16.82
Nitrate soda, 200 pounds per acre	157.0	139	139.7	113	56.28	54.91	15.34	14.08
Bone meal, 200 pounds per acre	163.6	154	149.0	127	59.20	56.23	16.71	15.86
Dried blood, 200 pounds per acre	164.0	144	138.6	119	58.10	54.08	14.88	15.29
2–12–2, 400 pounds per acre	166.5	156	143.3	128	60.87	58.57	15.98	16.03
3–12–4, 400 pounds per acre	170.3	159	155.0	131	62.61	58.18	16.12	16.76
Manure, 10 tons per acre	158.4	136	145.2	117	56.60	54.90	15.06	14.91

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The Influence of Nitrogen, Phosphorus, and Potash Separately and in Combination on Sweet Potato Production

By Fred W. Geise, *University of Maryland, College Park, Md.*

Introduction

THE study of sweet potato production in Maryland from the standpoint of fertilization is further complicated by the different soil and climatic conditions prevailing in the various producing regions. The literature on the subject of sweet potato fertilization suggests that not only such factors as soil conditions, variety differences, and the system of crop rotation influence production, but it seems that the matter of length of growing season is very important. Where the sweet potato crop has a relatively long growing season as in the South, other conditions being similar, the general fertilizer treatment varies as compared with the Middle Atlantic States region. In the Middle Atlantic States' region the application of a high grade fertilizer at the rate of 800 to 1500 pounds per acre is a common practice, probably in part due to the fact that the sweet potato plant is of tropical origin and hence. when grown in the northern region, must mature during a relatively short season. In this connection the results reported from the New Jersey Experiment Station by Voorhees, Schermerhorn and others are of particular interest.

Since it is evident that the length of season influences to some extent the fertilizer requirements, any study of fertilizer requirements must be sufficiently comprehensive to allow for the variations noted. It seemed advisable to plan the work so as to determine what influence the more important fertilizer elements separately and in combination have on the yield. The work* herein reported, deals only with that phase of experimental work just stated and does not deal with the problem of nitrogen and potash carriers. No comparison is made with different methods of fertilizer application. This phase of the experiment will be reported at a future time.

Two representative sweet potato producing regions were selected for study, one representing Maryland conditions on the Western

*The work herein reported is in part a continuation and an outgrowth of investigations started by Dr. H. A. Jones formerly of University of Maryland. Credit is due Mr. V. R. Boswell for his assistance in collecting part of the data.

shore of Chesapeake Bay, and the other on the Eastern shore. The object of the experiment is to show to what extent the nitrogen, phosphorus, and potassium, influenced production when used singly and in combination, and also when applied under different soil conditions, and over a period of several years. The plots used in this test were one-twentieth acre in area,, unless otherwise stated, and arranged in duplicate. Two days before the sweet potato plants were set in the field all the plots were given their respective treatments as indicated. The materials were distributed in rows from 12 to 15 inches wide, after which these rows were listed and the plants set on a list approximately 2 inches above the ground level.

The following ingredients were used in these tests:—

Nitrate of soda analyzing 18 per cent ammonia.
Dried blood analyzing 16 per cent ammonia.
Acid phosphate analyzing 16 per cent phosphoric acid
Muriate of potash analyzing 50 per cent potash
Ground limestone analyzing 97–98 per cent $CaCo_3$

The amount used is indicated in the accompanying tables. The Big Stem Jersey variety was selected and good production methods followed in the care and handling of the crop throughout the experiment.

TABLE I—Yield of Marketable Sweet Potatoes from Plots Treated with the Essential Elements; Nitrogen, Phosphorus, and Potassium, Separately and in Combination

Season 1921—Reddick Farm, Salisbury, Wicomico County, Maryland.
Average yield per acre from duplicate plots of one-twentieth acre each.

Plot	Pounds of fertilizer per acre		Yield in bushels	Per cent
1	Check*		64	100.0
3	Acid phosphate	600	65	100.1+
4	Muriate of potash	200	140	218.7+
5	Nitrate of soda Dried blood Acid phosphate	100 100 600	90	140.6+
6	Acid phosphate Muriate of potash	600 200	123	192.1+
7	Nitrate of soda Dried blood Muriate of potash	100 100 200	152	237.5
8	Nitrate of soda Dried blood Acid phosphate Muriate of potash	100 100 600 200	138	215.6+
9	Nitrate of soda Dried blood Acid phosphate Muriate of potash	100 100 600 400	178	278.1

*Check—average of seven plots.

Presentation of Data

Reddick Farm—Salisbury, Wicomico County, Maryland:—The soil conditions were typical of the Eastern shore sweet potato region. The field was in a fair state of fertility and the soil was classified as Norfolk sand.

The results as indicated in Table I show that the plots treated with muriate of potash, whether singly, in combination with nitrogen carriers, or with acid phosphate and nitrogen carriers, yielded considerably more marketable potatoes than any other plots included in the test. This particular test indicates that nitrogen and phosphorus are of minor importance as compared with potash. Potash gave the greatest response, particularly in plot 9.

Blandford Farm—Clinton, Prince George's County, Maryland:—The soil was classified as of the Sassafras gravelly loam type, and the field was in a fair state of cultivation. The field the previous season had been devoted to a corn crop, followed with a fall and winter crop of rye which was turned under as green manure. Just before planting time a lime requirement test showed the soil to be very strongly acid. To one-half of the field designated Block A, lime was applied at the rate of 6,000 pounds of calcium carbonate per acre per year in order to neutralize the soil acidity. The records from the two parts of the field were kept separate.

A comparative study of the actual yields from the limed and unlimed plots show the benefits derived from the application of lime to a strongly acid soil of the type used in the test. The limed plots outyielded the unlimed plots in all cases except plot 2, in 1921 when the unlimed plot exceeded the limed.

In Block A, season 1921, limed, the yields were uniformly greater than the check, yet there was relatively little difference among the various treatments. The application of nitrogen and phosphorus singly or in combination showed increased yields as compared with check. Those plots having been treated with muriate of potash, either singly or in combination are slightly better than those having had no potash treatment.

In Block B, season 1921, unlimed, the data indicate that nitrogen, either singly or in combination, is more important than either phosphorus or potash in increasing the yield. This suggests that on a soil relatively low in nitrogen and very strongly acid, any addition of nitrogen, particularly nitrate of soda, would influence the yield.

Due to unseasonal conditions resulting in a poor stand on some plots in 1922, the data are incomplete and do not permit much in the way of comparison of the various fertilizer treatments.

Cheltenham Experiment—Prince George's County, Maryland:—1923–1924–1925.—The soil in these tests was of the Sassafras sandy loam type. The field used in 1923 was planted to rye during the fall of 1922 and the crop plowed down preparatory to the sweet potato crop. A lime requirement test showed the soil to be practically neutral. The field used in 1924 was adjacent to the first field and treated in a similar manner. The 1925 test plots occupied the same field as in 1923.

TABLE II—YIELD OF MARKETABLE SWEET POTATOES FROM PLOTS TREATED WITH THE ESSENTIAL ELEMENTS, NITROGEN, PHOSPHORUS AND POTASSIUM SEPARATELY AND IN COMBINATION

Season 1921 and 1922—Blandford Farm, Clinton, Prince George's Co.
Average yield per acre. Plots of one-fortieth acre each. Block A. $CaCO_3$ 6000 pounds per acre.
Block B.—Unlimed. Plots for season 1922 in duplicate only.

Plot	Pounds of fertilizer per acre	Season of 1921				Season of 1922*			
		Block A—limed		Block B—unlimed		Block A—limed		Block B—unlimed	
		Yield in bushels	Per cent	Yield in bushels	Per cent	Yield in bushels	Per cent	Yield in bushels	Per cent
1	Check	65	100.0	42	100.0	38	100.0	20	100
2	Nitrate of soda 100 Dried blood 100	85	130.7	101	240.4+	—	—	—	—
3	Acid phosphate 600	87	133.8+	54	128.5+	88	231.5+	40	200
4	Muriate of potash 200	99	152.3+	59	140.4+	154	405.2+	114	570
5	Dried blood 100 Nitrate of soda 100 Acid phosphate 600	89	136.9+	73	173.8+	—	—	—	—
6	Acid phosphate 600 Muriate of potash 200	90	138.5+	51	121.4+	225	592.1+	120	600
7	Nitrate of soda 100 Dried blood 100 Muriate of potash 200	90	138.5+	77	183.3	184	484.2+	175	875
8	Nitrate of soda 100 Dried blood 100 Acid phosphate 600 Muriate of potash 200	97	149.2+	55	130.9	163	428.9+	147	735

*Poor stand due to unseasonal conditions—1922.

TABLE III—Yields of Marketable Sweet Potatoes from Plots Treated with the Essential Elements, Nitrogen, Phosphorus, and Potassium, Separately and in Combination

Seasons 1923, 1924 and 1925—Cheltenham—Prince George's County
Average yield per acre from duplicate plots of one-twentieth acre each

Plot	Pounds of fertilizer per acre		Season of 1923		Season of 1924*		Season of 1925	
			Yield in bushels	Per cent	Yield in bushels	Per cent	Yield in bushels	Per cent
1	Check		109	100.00	124	100.00	135	100.00
2	Nitrate of soda Dried blood	87 200	103	94.49+	126	101.60+	147	108.80+
3	Acid phosphate	600	118	108.20+	—	—	177	131.10+
4	Muriate of potash	200	173	158.70+	135	108.80+	241	178.50+
5	Nitrate of soda Dried blood Acid phosphate	87 200 600	138	126.50+	153	123.30+	127	93.33+
6	Acid phosphate Muriate of potash	600 200	196	179.80+	—	—	175	129.60+
7	Nitrate of soda Dried blood Muriate of potash	87 200 200	186	176.40+	135	108.80+	262	193.30+
8	Nitrate of soda Dried blood Acid phosphate Muriate of potash	87 200 600 200	179	164.20+	—	—	254	188.10+

*Data for season 1924 are incomplete due to unseasonal conditions at time of planting.

The yields for the season 1923—Table III—showed that potash, under the conditions of the particular test, played an important role in production. The addition of nitrogen or phosphorus did not increase the yield in proportion to the potash treated plots, however, some benefits were derived from the use of these ingredients.

The data for 1924 are incomplete due again to the unseasonal conditions at the time of planting, extremely cold and wet weather prevailed at that time. It is interesting to note that the nitrogen-phosphorus plot yielded more than the nitrogen-potash plot.

The 1925 results parallel rather closely the results of 1923, in which potash is shown to be very effective. The results secured from nitrogen and phosphorus were inconsistent.

Discussion of Data

The harvest yields as indicated by Table I, II and III, seem to show generally that the response from potassium is greater than from nitro-

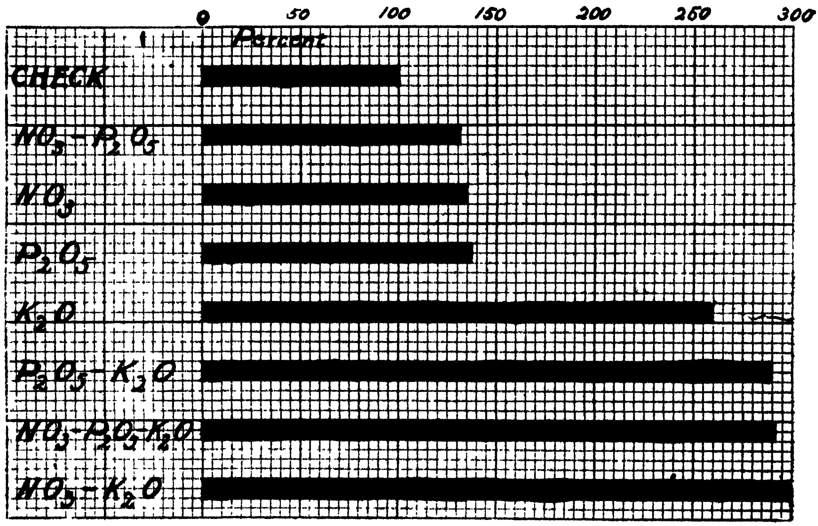

FIG. 1 Note the percentage increase over check when the different fertilizer elements were used. Potash, especially, has increased yields.

gen and from phosphorus when used separately and in combination. It is now desirable to determine whether or not such results are consistent when applied over a period of several years and under different soil conditions.

By converting the actual yields obtained from the various tests and plots into percentages, based on the check in each case, the results may then be added and averaged for each treatment and compared on a relative basis. Graph I shows a summary of the relative yields expressed in per cent in which case the check represents 100 per cent.

In summarizing the results the graph shows that plots treated with nitrogen, phosphorus, and with nitrogen-phosphorus, have an average increase over the average of the check plots. These average increases are 35.2 per cent, 37.7 per cent and 32.4 per cent respectively. In the plots treated with potash, phosphorus-potash, nitrogen-potash and with nitrogen-phosphorus-potash, the average increase over the average of the check plots shows 160.5 per cent, 179.1 per cent, 199.6 per cent and 187.4 per cent respectively.

In terms of actual acerage increase in bushels the following results are obtained:—

Plot	Treatment	Average, bushels	Increase, bushels
1	Check	74.6	—
2	Nitrate of soda Dried blood	112.4	37.8
3	Acid phosphate	89.8	15.2
4	Muriate of potash	139.5	64.9
5	Nitrate of soda Dried blood Acid phosphate	111.6	37.0
6	Acid phosphate Muriate of potash	140.0	65.4
7	Nitrate of soda Dried blood Muriate of potash	132.6	58.0
8	Nitrate of soda Dried blood Acid phosphate Muriate of potash	147.5	72.9

The data clearly show that under these conditions a complete fertilizer is essential in sweet potato production since each of the three elements when used singly give an increase in yield as compared with the check plot. Potash gives the greatest increase, nitrogen second, and phosphoric acid seemed to be of less importance than either as indicated by the small increase in yield.

It is interesting to note that Maryland has recommended to its growers under similar conditions a fertilizer analyzing 3 per cent ammonia, 8 per cent phosphoric acid, and 8 per cent potash. It seems that this recommendation is largely the result of experience. The low nitrogen and the high potash analysis can be explained on the basis of the data presented. The only explanation for the relatively high phosphoric acid, it seems, is that the cost of acid phosphate as a filler and conditioner in a high analysis fertilizer is only slightly more than some inert filler and conditioner, and that the trade is largely responsible for the high phosphorus content that is being used. The advantage of using acid phosphate then would be in adding a certain amount of phosphate to the soil for future needs. One year's results are available under Eastern Shore of Maryland conditions which show a comparison in yields of 4 of the most widely used fertilizer analyses in sweet potato production.

Van Horn Farm, Salisbury, Wicomico County, Maryland:—The soil was of the Norfolk sand type and the field had been cleared of pine woods about 5 years ago. The following fertilizer ingredients were used in making the various analyses.

One-half of nitrogen from nitrate of soda 18 per cent.
One-half of nitrogen from dried blood 16 per cent.
Phosphorus from acid phosphate 16 per cent.
Potassium from muriate of potash 50 per cent.

The fertilizer was applied at the rate of 1000 pounds per acre and similar methods of distribution followed as in preceding tests. The Big Stem variety was again grown.

TABLE IV—YIELD OF MARKETABLE SWEET POTATOES FROM PLOTS TREATED WITH FERTILIZERS IN WHICH THE AMOUNT OF NITROGEN AND POTASH HAS BEEN VARIED

Season 1924—Van Horn Farm, Salisbury, Wicomico Co.
Average yield per acre from duplicated plots one-twentieth acre each

Plot	Pounds of fertilizer per acre	Yield in bushels	Per cent
1	Check*	108	100.00
2	1000 of 2–8–8	134	124.08+
3	1000 of 2–8–10	174	161.10+
4	1000 of 3–8–8	134	124.08+
5	1000 of 3–8–10	157	145.30+

*Average of 4 plots.

A comparison of the yields from the different plots indicates that a 2–8–10 as compared with a 2–8–8 is to be preferred, also that the 3–8–10 out-yielded the 3–8–8. There was no response from the use of increased nitrogen. It should, however, be noted that these results represent only one season's work and at best should only be taken as an indication of what may be expected in further work of this kind.

CONCLUSION

A five year study of the influence on yield of nitrogen, phosphorus and potash when used separately and in combination gave the following results. In the plots treated with nitrogen, phosphorus, and with nitrogen-phosphorus, the average relative increases over the average of the check plots were 35.2, 37.7 and 32.4 per cent respectively. In the plots treated with potash, phosphorus-potash and with nitrogen-phosphorus-potash the average relative increases over the average of the check plots, showed 160.5, 179.1 and 187.4 per cent respectively. The plots having been treated with muriate of potash either singly or in combination with nitrogen or with nitrogen-phosphorus gave the largest increase of any of the treated plots.

A comparative study of the actual yields from limed and unlimed plots showed that decided benefits were derived from the application of lime to a strongly acid soil of the type used in some of the tests.

One season's comparison in yields of 4 of the most widely used fertilizer analyses in Maryland in sweet potato production showed that a 2–8–10 analysis out-yielded a 2–8–8, and also that the 3–8–10 out-yielded the 3–8–8 in production of marketable potatoes.

Effect of Nutrition on the Number of Blossoms per Cluster and the Dropping of Blossoms in the Tomato

By H. R. Kraybill, *Boyce Thompson Institute, Yonkers, N. Y.*

On account of the numerous requests for information regarding the causes of the dropping of blossoms in tomatoes received by the Office of Horticulture and Pomology of the Bureau of Plant Industry, Prof. L. C. Corbett requested me to take up a study of the problem. Kraus and Kraybill have shown that maximum fruitfulness is associated neither with highest nitrogen nor highest carbohydrate content of the tomato plant, but with a condition of balance between them, and that the ratio of total nitrogen to carbohydrate within the plant can be modified by changing the supply of available nutrient salts. In view of these facts it was thought desirable to determine, if possible, to what extent nutrient conditions might be responsible for the dropping of blossoms under field conditions. As a result of these studies a few notes were obtained which indicate the effect which nutrient conditions may have upon the dropping of blossoms under controlled greenhouse conditions.

Fifteen hundred pounds of surface soil obtained from numerous parts of a field near Whiteford, Maryland, in which considerable dropping of blossoms occurred in 1917, were secured and shipped to Arlington Farm. The soil was mixed thoroughly and 17 pounds placed in each 10-inch earthenware pot. The fertilizer as follows was mixed thoroughly throughout the soil in each of the pots:

Lot A—No fertilizer
Lot B—No fertilizer
Lot C—25 grams dried blood, 43 grams acid phosphate, 3 grams K_2SO_4.
Lot D—25 grams dried blood, 43 grams acid phosphate, 3 grams K_2SO_4.
Lot E—25 grams dried blood, 168 grams acid phosphate, 64 grams K_2SO_4.
Lot F—25 grams dried blood, 168 grams acid phosphate, 64 grams K_2SO_4.
Lot G—25 grams dried blood, 168 grams acid phosphate, 3 grams K_2SO_4.
Lot H—25 grams dried blood, 168 grams acid phosphate, 3 grams K_2SO_4.

On the basis of 3650 plants per acre, the amounts of fertilizer per plant were the same as under field treatments of the following applications per acre:

Lots C and D—600 pounds of a 4–8–2 fertilizer.
Lots E and F—600 pounds of a 4–8–2 fertilizer, 1000 pounds of acid phosphate and 500 pounds of K_2SO_4.
Lots G and H—600 pounds of a 4–8–2 fertilizer, and 1000 pounds of acid phosphate.

Seed of a pure strain of Stone tomato was sown in flats according to the usual practice. The plants when 2 inches high, were trans-

TABLE I—DATA UPON THE FIRST CLUSTER TAKEN JUNE 7, 1918

Plant number	Number of blossoms				Number of fruits developed				Number of fruits undeveloped				Number of blossoms dropped			
	A and B	C and D	E and F	G and H	A and B	C and D	E and F	G and H	A and B	C and D	E and F	G and H	A and B	C and D	G and H	E and F
1	3	5	9	5	1	4	4	3	1	0	4	1	1	1	1	1
2	4	5	5	6	1	4	3	4	1	1	2	2	2	0	0	0
3	4	6	5	6	2	4	4	4	2	1	1	2	0	1	0	0
4	3	5	6	6	2	4	4	3	0	0	2	3	1	1	0	0
5	4	6	6	5	1	3	4	3	3	3	2	0	0	0	0	0
6	3	6	5	6	2	4	3	4	1	2	1	0	0	0	1	2
7	4	6	5	5	2	3	3	4	1	3	2	0	1	0	0	1
8	4	6	6	6	2	4	4	5	1	2	2	1	1	0	0	0
9	3	–	–	–	1	–	–	–	0	–	–	–	2	–	–	–
1	3	6	5	9	1	4	5	7	2	2	0	2	1	0	0	0
2	4	5	3	5	1	3	3	4	3	2	0	1	0	0	0	0
3	4	5	5	5	2	3	4	3	1	1	1	1	1	1	0	2
4	3	9	6	5	0	5	3	5	2	4	2	0	1	0	1	1
5	4	5	5	6	3	3	4	4	0	2	1	1	1	0	0	0
6	3	6	5	6	2	4	4	4	0	2	1	1	1	0	0	1
7	3	5	6	6	1	5	5	4	0	0	1	1	1	0	0	1
8	3	5	5	5	1	3	4	5	2	2	0	0	0	0	1	0
9	3	–	–	–	2	–	–	–	0	–	–	–	1	–	–	–
10	4	–	–	–	2	–	–	–	1	–	–	–	1	–	–	–

TABLE II—DATA UPON THE SECOND CLUSTER TAKEN JUNE 24, 1918

Plant number	Number of blossoms				Number of fruits developed				Number of fruits undeveloped				Number of blossoms dropped			
	A and B	C and D	E and F	G and H	A and B	C and D	E and F	G and H	A and B	C and D	E and F	G and H	A and B	C and D	B and F	G and H
1	5	3	6	6	2	2	2	3	2	0	2	2	1	1	2	1
2	5	6	6	6	0	2	2	3	0	4	2	3	5	0	2	0
3	3	7	6	5	0	2	1	2	0	1	5	3	3	4	0	0
4	4	6	6	6	0	5	2	2	2	0	4	1	2	1	0	3
5	3	6	6	5	0	2	3	2	2	3	3	2	1	1	0	1
6	3	6	6	2	0	4	2	2	0	1	2	0	3	1	2	0
7	3	6	5	6	0	2	4	4	0	3	1	1	3	1	0	1
8	4	6	7	6	0	4	3	3	1	2	2	3	3	0	2	0
9	2	–	–	–	0	–	–	–	1	–	–	–	1	–	–	–
1	3	6	8	5	0	3	3	0	1	3	5	3	2	0	0	2
2	3	6	6	5	0	2	4	2	0	3	2	2	3	1	0	1
3	4	6	5	6	0	3	2	1	3	3	3	3	1	0	0	2
4	4	6	6	6	1	3	3	3	2	2	1	2	1	1	2	1
5	5	6	6	6	2	2	2	1	2	3	4	5	1	1	0	0
6	3	6	6	5	0	2	2	3	2	3	4	1	1	1	0	1
7	2	5	6	6	0	3	2	3	0	2	3	2	2	0	1	1
8	3	6	6	6	0	1	4	0	0	4	2	5	3	1	0	1
9	4	–	–	–	0	–	–	–	4	–	–	–	0	–	–	–
10	4	–	–	–	1	–	–	–	1	–	–	–	2	–	–	–

TABLE III—SUMMARY OF NUMBER OF BLOSSOMS PER CLUSTER, NUMBER OF FRUITS DEVELOPED, NUMBER OF FRUITS UNDEVELOPED AND PERCENTAGE OF BLOSSOMS DROPPED

Lot	Average number of blossoms	Average number of fruits developed	Average number of fruits undeveloped	Per cent blossoms dropped	Average number of blossoms	Average number of fruits developed	Average number of fruits undeveloped	Per cent blossoms dropped
A	3.5	1.6	1.2	25.0	3.0	0.0	0.8	73.3
B	3.5	1.5	1.1	25.7	3.3	0.2	1.4	50.0
C	5.6	3.7	1.5	6.6	5.7	2.8	1.7	19.5
D	5.7	3.7	1.8	2.1	5.8	2.3	2.8	10.6
E	5.8	3.6	2.0	4.3	6.0	2.3	2.6	16.6
F	5.0	4.0	0.7	5.0	6.1	2.7	3.0	6.1
G	5.5	3.7	1.2	9.9	5.2	2.6	1.8	14.2
H	6.0	4.5	0.8	10.4	5.6	1.6	2.8	20.0

ferred to five-inch pots in fertile soil. When the plants were about 16 inches high, April 17, 1918, they were transplanted to the ten-inch pots. The plants at this time were only medium in vigor and the first blossom cluster was just appearing. In transplanting, the soil was washed from the roots and the plants were set 2 to 3 inches deeper in the new pots than they were in the pots from which they were taken. Duplicate lots of plants of each treatment were placed so that possible differences in position in the greenhouse would be overcome. Ordinary tap water was used in watering the plants. The blossoms were carefully hand pollinated every other day to insure against dropping of blossoms caused by lack of pollination.

On April 30 the plants of lots A and B were slightly yellowish green in color and less vigorous than those of the other lots. On May 8, 4 plants of lot A received fertilizer treatments as follows: A_1, 25 grams of dried blood, A_2, 43 grams of acid phosphate, A_3, 3 grams of K_2SO_4, and A_4, 43 grams of acid phosphate and 3 grams of K_2SO_4. On May 20, plant A_1, which had received the application of dried blood, was deeper green in color and more vigorous. Plants A_2, A_3 and A_4 showed no differences due to the second application of the fertilizer. Subsequently sodium nitrate was applied to several of the plants from lots A and B. Very soon these plants became deeper green in color and grew more vigorously. Apparently the effectiveness of the fertilizer treatments was due largely to the nitrogen.

Tables I and II show the number of blossoms per cluster, the number of fruits developed, the number of fruits undeveloped, and the number of blossoms dropped for the first and second cluster of each plant. Table III gives the average results for the plants of each lot.

The data show that the number of blossoms per cluster, the number of fruits which develop and grow per cluster, the number of fruits which remain undeveloped per cluster, and the number of blossoms which drop, can be influenced by modifying the amounts of available mineral nutrients under conditions of uniformity with reference to other external factors.

The Importance of Phosphorus in the Production of Seed and Non-seed Portions of a Tomato Fruit

By J. H. MacGillivray,* *Experiment Station, Lafayette, Ind.*

THE earlier agricultural workers attributed to many elements a primary function in the growth and production of a certain part of plants. These ideas, although found only rarely in recent publications, are still very frequently heard among agricultural workers.

*The above data were obtained while the author was a member of the Botanical Department of the University of Wisconsin and he is indebted to Dr. E. J. Kraus for helpful criticisms and suggestions.

Thus phosphorus has been accorded the importance of being primarily essential for seed production. This statement can in all fairness be given 2 interpretations, however, it is unlikely if the first explanation is very widely recognized outside of educational institutions. Phosphorus is essential for the formation of inherent parts of all cells. As seeds consist of cells as units, phosphorus must be necessary for the formation of seed. The second interpretation of this statement concerning the importance of phosphorus is unfortunately the most widely accepted, and is likely erroneous for horticultural fruits. Phosphorus is considered essential for the production of seed and only of minor importance in the production of the non-seed portions of the plant such as leaves, stems, roots and non-seed portions of the fruit.

Much of the agricultural experimental work of the last half century, especially from the chemical standpoint, has been largely confined to cereal grains. These research workers found (Wilfarth, Romer and Wimmer, 1905, and others) that in the mature cereal plant over one half of the phosphorus was in the kernel. Increased grain production as well as increased earliness of ripening usually was recorded from the use of phosphate fertilizers. These earlier analyses together with the effect of phosphorus on grain production, seems a legitimate cause for the statement that phosphorus is essential primarily for seed formation in cereal grains. There is need of further evidence before this should be accepted in the field of horticulture where the non-seed portion of most fruits is so large. In the tomato as much as 99 per cent of the green weight of the fruit may be the non-seed portion; while it rarely falls below 95 per cent. This preponderance of the non-seed portion of horticultural fruits is worthy of more attention. The agronomists may have overlooked one possibility in connection with the chemical results mentioned in this paragraph. It is undoubtedly true that the amount of phosphorus found in the ripe kernel is over 50 per cent, but likely a portion of this element was removed from the leaves, stems and roots as the plant matured. Although this phosphorus was found at maturity in the seed, it was a part of the physiological processes of another part of the plant in its earlier development. The proof of the re-utilization of phosphorus in the tomato will be given in a later paper.

METHODS

The plants used in this experiment were Bonny Best and the seed was obtained from Olds Seed Store, Madison, Wisconsin. A rich garden soil was used to grow the plants which were shifted from the seed flat successively to 2 and 4 inch pots. Before the first blossom cluster opened, the plants were set in the greenhouse bench during the spring of 1924 and the summer of the same year. To insure a difference in the fertility of the soil in the two tests, the soil in the last experiment was supplemented with a liberal amount of sheep manure and steamed bone meal. These experiments are referred to as the April-June and August-September series according to the time

the fruit ripened. Plants were also grown in sand under two phosphorus nutrient treatments.

The phosphorus analyses were made according to the official volumetric method for agricultural chemists. The dry weights were obtained by drying in partial vacuum at 98° C. The tissue had been previously ground until it would pass through a screen with 50 meshes per square inch.

As it is difficult to select any very definite stages in the maturity of the tomato, the following method was adopted and used successfully. The youngest stage was selected on the basis of number of days from pollination and size of ovary. Fruits of 3 to 5 mm. in diameter were used which had been pollinated 3 to 5 days previously. It was necessary to take the date of pollination into consideration to exclude fruits which had only started ovary development, but would never produce a mature fruit. The second stage based primarily on size included fruits of three-fourths to 1 inch in diameter. The fruit of this stage was approximately 3 weeks old. The length of the period from pollination to maturity fluctuated so much in the other stages as to make this data of questionable value. The other stages were selected by the color of the fruit and the firmness as shown by testing in the palm of the hand. The older stages were—hard green, soft green and ripe. All fruits except those of the youngest stage were separated into seed and surrounding pulp, and the pulp of the outer and intra carpel walls. This was done by removing the seed and surrounding pulp from the locule through severance at its innermost point of attachment.

TABLE I—ANALYSES OF TOMATO FRUITS OF APRIL–JUNE SERIES GROWN IN THE GREENHOUSE IN RICH GARDEN SOIL

	Per cent of phosphorus based on dry weight	Per cent of phosphorus based on green weight	Total amount of phosphorus per fruit in mg.	Total dry weight per fruit in grams	Total green weight per fruit in grams	Per cent of dry matter
Pulp						
¾–1mm. in diam.	.571	.0410	1.550	.272	3.79	7.17
Hard green	.465	.0378	11.380	2.452	81.08	3.02
Soft green	.361	.0157	21.850	6.072	138.97	4.36
Ripe	.362	.0174	26.180	7.232	150.24	4.81
Seed and surrounding pulp						
3–5 mm. in diameter	1.570	.0017	.053	.0035	.0304	11.51
¾–1 mm. in diameter	.793	.0244	1.205	.152	2.44	6.23
Hard green	.683	.0380	7.957	1.165	20.98	5.55
Soft green	.582	.0398	17.170	2.951	43.25	6.82
Ripe	.567	.0372	16.310	2.876	43.78	6.56

The plants used in the nutrient treatment were grown in a similar manner except that they were transplanted from 4 inch pots to pure quartz sand. The no phosphorus plants (OP) received a nutrient

solution containing all the essential elements except phosphorus, while the ample phosphorus plants (AP) received a nutrient solution containing all the essential elements. Equal numbers of the fruits at the different stages were used for analysis.

TABLE II—ANALYSES OF TOMATO FRUITS OF AUGUST–SEPTEMBER SERIES GROWN IN THE GREENHOUSE IN RICH GARDEN SOIL SUPPLEMENTED WITH STEAM BONE MEAL AND SHEEP MANURE

	Per cent of phosphorus based on dry weight	Per cent of phosphorus based on green weight	Total amount of phosphorus per fruit in mg.	Total dry weight per fruit in grams	Total green weight per fruit in grams	Per cent of dry matter
Pulp						
¾–1 mm. in diam.	.561	.0490	1.270	.2270	2.6500	8.56
Hard green	.589	.0280	10.810	1.8350	38.5100	4.76
Soft green	.646	.0219	20.170	3.1230	91.7300	3.40
Ripe	.576	.0288	24.860	4.3160	86.1400	5.01
Seed and surrounding pulp						
3–5 mm. in diameter	1.400	.0015	.054	.0038	.0348	10.91
¾–1 mm. in diam.	.805	.0261	1.123	.1394	2.1500	6.48
Hard green	.666	.0348	5.350	.8030	15.4400	5.20
Soft green	.633	.0405	10.980	1.7350	27.0500	6.41
Ripe	.777	.0309	15.010	1.9320	48.6100	3.97

TABLE III—FRUITS FROM PHOSPHORUS NUTRIENT TREATMENT GROWN IN PURE QUARTZ SAND IN GREENHOUSE, SPRING OF 1924

	No phosphorus				
	Phosphorus per cent based on dry weight	Phosphorus per cent based on green weight	Per cent dry matter	Dry weight per plant	Mg. phosphorus per plant
Fruit pulp	.197	.0108	8.73	1.459	2.875
Fruit seed and surrounding pulp	.346	.0302	5.49	.344	1.191

	Ample phosphorus				
	Phosphorus per cent based on dry weight	Phosphorus per cent based on green weight	Per cent dry matter	Dry weight per plant	Mg. Phosphorus per plant
Fruit pulp	.488	.0289	5.92	8.915	43.50
Fruit seed and surrounding pulp	.622	.0508	8.16	3.888	24.18

DISCUSSION

The method used to separate the fruit into 2 regions is not ideal, as it includes with the seed approximately 20 per cent of the green weight of the fruit's non-seed portion. Since it is impossible to separate the seed and pulp satisfactorily in the young fruits, a uni-

form method was used throughout. The method in no way affects the conclusions in this paper as it decreases the actual amount of phosphorus which should be credited to the pulp. A member of the legume or cabbage family where the carpel wall and seed are more distinctly separate at all stages of maturity would be more desirable for this study.

The total amount of phosphorus found in the seed and non-seed parts of a fruit should give a distinct decision as to the importance of this element in their formation. The data given in Tables I and II indicate that the percentage of phosphorus found in the seed portion is always greater than in the non-seed portion of the fruit. The non-seed part of the fruit always has a greater dry and green weight than the seed portions. This greater amount of dry matter in the pulp portion is the reason for always finding a greater total amount of phosphorus in the non-seed portion of the fruit.

Embryonic regions usually contain a high percentage of phosphorus which fact is confirmed by the greater percentage of phosphorus found in the young fruits. The importance of the element in the more mature stages is shown by the fact that the amount of phosphorus in the 2 regions steadily increases with age even though the percentage of phosphorus decreases as the fruit approaches maturity. This is surprising when one considers from the cellular standpoint ripening in a tomato is primarily an increase in the size of cells. No embryonic regions are found in the more mature stages. The importance of phosphorus in the production of the non-seed portion is clearly shown by the greater amount of phosphorus found in this region as well as the effect of phosphorus nutrient treatment on this relationship.

The analysis of tomatoes grown under different phosphorus nutrient treatments in pure quartz sand is given in Table III. Here again the amount found in the non-seed portion of the fruit is greater under both nutrient treatments. If phosphorus is essential primarily for seed production, it is possible under a limited phosphorus supply that the seed would be able to obtain this element at the expense of the pulp. The plants grown in the absence of phosphorus contain 29.3 per cent of the phosphorus of the fruit in the seed, while plants grown in the presence of an ample supply contain 35.7 per cent of the phosphorus in the seed. The presence of phosphorus in greater quantities in the non-seed portion of the fruit regardless of age or phosphorus nutrient treatment, demonstrates that phosphorus is just as important in the production of the non-seed portion as the seed portion of the fruit.

Quality in tomato fruits, if stated in 3 words, would be confined to color, flavor and solids, or dry weight of fruit. Thus the non-seed portion of a tomato must be of primary importance in considering quality. Limiting supplies of phosphates reduces yield both by a decreased number of fruits per plant and a decreased size of the individual fruits. These small fruits, grown on plants receiving no phosphorus in the nutrient solution, show a marked difference in their

internal appearance. Their outer and intra carpel walls are very narrow in comparison with the fruits grown in the presence of an ample supply of phosphorus. What effect would this have on the quality of tomatoes from the standpoint of home use, canned tomatoes, and tomato products? The low phosphorus tomato would be unsatisfactory to slice because of the small amount of carpel wall material or what is termed "Meatiness." This thin wall would affect the quality of whole canned tomatoes. Injury during peeling would be more serious as well as greater breakdown during the sterilization of the canned product. High quality canned tomatoes should contain all whole tomatoes when the can is opened. The thin carpel walls would likely produce canned tomatoes broken into small pieces. Producers of tomato products would be interested in the amount of waste from this type of fruit as compared with fruits from well fertilized vines. The amount of skin per ton of fruit would seem to be greater from small fruits as compared to large fruits. It is important to know the per cent of seed found in low phosphorus fruits as compared to fruits receiving an ample supply. A very important problem would be the effect of these nutrient treatments on the acid and sugar ratio which many feel is primarily responsible for the flavor of the tomato. An element such as phosphorus which is so important in producing the non-seed portion of the fruit must be necessary to produce high quality tomato fruits. Studies are in progress at the Purdue Agricultural Experiment Station to obtain measurements of tomato quality and to obtain methods of improving tomato quality.

Summary

There is more total amount of phosphorus in the non-seed part of a tomato fruit than in the seed part regardless of maturity or phosphorus nutrient treatment. Phosphorus is just as essential for the production of the non-seed as the seed portion of a tomato fruit.

Literature Cited

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A Study of Some Environmental Factors Influencing the Shooting to Seed of Wintered Over Cabbage

By V. R. Boswell, *University of Maryland, College Park, Md.*

Introductory

SINCE the time allotted for the reading of this paper is very brief, and since space in the publication of the proceedings of the society is at a premium, it is necessary to omit the details of the methods used in the experiments herein reported, and confine the discussion to only the salient points of the problem. Work is still in progress. A detailed description of the methods and a complete presentation of results will appear upon the termination of the project.

Statement of the Problem

In sections of the Middle- and South-Atlantic states where the weather is mild enough for cabbage to live through the winter with no artificial protection, it is a common practice to sow the seed in the fall and transplant to the field in the early winter. Of course, no growth is made during the winter, but the advantage is gained that with the earliest growing weather in the spring, the plants resume growth and are ready for market sooner than spring grown plants. Some losses occur from winter killing, and also a varying amount of loss is suffered as a result of the plants shooting to seed instead of forming heads. The percentage of "seeders" appearing, varies greatly from year to year in the same location and varies greatly on different farms in a given season.

The widely different views as to the cause of this formation of flower stalks, and the varying practices in vogue in the production of the crop, are evidences of the lack of information concerning the factors which control the phenomenon. It is known that genetic factors play a part in "bolting" of cabbage, as it is sometimes called. Many investigators (2) (4) (5) (6) have made note of this fact. But hereditary factors do not account for the behavior entirely. Some hold that it is determined by cultural conditions (3), while it is more probable that both genetic and environmental factors play a part. We shall be concerned here chiefly with the environmental factors.

The environmental conditions variously supposed to be responsible for the formation of flower stalks instead of heads are: Warm, open winters; very severe winters; extreme changes in winter temperature; checking of growth in the plant bed, soil conditions, and even the mode of transplanting. Growers have learned that the time of planting the seed is an important factor, and many always plant on a certain date if it is at all possible. The soil conditions can be controlled to some extent and the plants may be subjected to varying climatic conditions by sowing the seed at different dates. These latter 2 factors are the ones which most growers attempt to control, and by the very nature of the case, they are about the only ones

which they can control. Accordingly, the major portion of this work was devoted to a study of the influence of: (1) time of planting the seed, (2) fertilizer treatment in the plant bed, and (3) fertilizer treatment in the field. Other points which were studied are: (1) influence of winter protection, (2) influence of the chemical composition of the plant on its subsequent behavior, and (3) behavior of different strains.

METHODS

Materials. Early Jersey Wakefield cabbage was used in the greater part of the work of 1923 and 1924, and in the latter year the Warren Wakefield was studied in a more limited way. In the first season's work some Copenhagen Market was started, but it was all winter killed.

Plant bed management. In 1923 no fertilizer plots were planned for the plant bed. A small uniform area of but medium fertility was seeded in rows a foot apart, and 3 sowings were made: August 25, September 5 and September 15. (The usual dates of sowing the seed vary in different localities.) The plant bed was maintained in a state of good culture. The 1923 results suggested the use of fertilizer treatments in the plant bed, so in 1924 one-half of the bed was given an application of a readily available 7–6–5 fertilizer at the rate of 1000 pounds per acre before planting. The seed was sown in rows running across both the fertilized and non-fertilized areas on September 2, 6, 10 and 15. After the plants were well established, the fertilized areas were given a top dressing of nitrate of soda at the rate of 200 pounds per acre. A second application was given on October 6 after a period of heavy rains.

Field management. Ridges about 18 inches high were listed up 3 feet apart in an east and west direction. A 7–6–5 fertilizer was applied under the ridge, but near the surface. In one exception which will be discussed later, a spring application only of excessive amounts of various fertilizers was given as a top dressing. Two applications of nitrate of soda of 200 pounds per acre were given to all complete fertilizer plots. The plants were transplanted to the field November 26 and 27, 1923; and November 17 and 18, 1924. They were set about half way up the south side of the ridge. All plots were triplicated in the field.

Data recorded. In 1923 a system was devised whereby notes could be taken at intervals on the size, vigor, and type of development of each individual plant in the experiment. The date of harvest and the weight of each head were also recorded. Thus a complete history of the condition and behavior of nearly 5000 individual plants was secured. The same scheme was started in the fall of 1924, but unfortunately the plants were covered with a heavy, compact mass of snow and ice for several weeks; and so very many plants were obliterated that the positions of the surviving plants could not be located on the record sheets. In 1924, records on winter-killing, percentage of seeders and yields could be taken only on a row basis instead of on a plant basis. The counts of seeders were made the first week in May.

Samples for analysis. In 1923, duplicate samples of at least 10 plants each were taken from the plant bed and from the field at intervals to determine what chemical differences might be associated with differences in condition and behavior of the plants. In the spring, samples of seeders and non-seeders were taken. In the second year's work, samples were taken at more frequent intervals. Samples for analysis were taken from a composite sample of no less than 15 plants. They were taken in duplicate. The tables which follow are self-explanatory in this connection.

Analytical methods. Lack of time and space forbids a discussion of the methods of analysis here. Let it suffice to say that they were essentially the same as those described in the proceedings of this society for 1924 on pages 179 to 180.

Influence of the Time of Planting and the Fertilizer Treatment on the Type of Plant Produced

Table I shows the distribution of different sizes of plants of various states of vigor. The classification into "small," "medium" and "large" plants as well as the description of the vigor as "poor," "medium" and "good" is purely arbitrary. The classification was made merely by observation and no measurements were taken. "Small" plants were about 3½ inches in height or smaller, taking the point of attachment of the lowest leaves as the base. The "medium" plants were from 3½ to 5 inches, and the "large" plants above about 5 inches in height above the leaf bases. Such a method of grouping is subject to error, but when the same person takes all the data on a large number of plants it should give some index to the relative sizes of the plants in the various plots.

The table shows that: (1) the earlier the seed is sown under any given plant bed treatment, the greater is the percentage of large plants which are available for transplanting, (2) for a given planting date, the fertilizer area in the plant bed produces a considerably higher percentage of large plants than does the unfertilized area, and (3) the large quantity of fertilizers used produced a higher percentage of plants of poor vigor in every case. None of these results are surprising, but they are emphasized here because of the bearing they have on the data which are to be discussed later. It may be quite possible to obtain the desired *size* of plant by heavy feeding, but may we not lose more hardiness by forming succulent growth than we can gain by increasing the size of the plant?

Influence of Time of Sowing Seed on Winter Killing and on Flower Stalk Formation

Table II is arranged to show the effect of varying the date of sowing the seed when other factors are kept constant. The planting date was varied under 4 different fertilizer treatments, and in each one it is to be seen at a glance that the plants from the earlier sowings produce a much higher percentage of flower stalks than those from the later ones. With 1 exception, each successively later planting results in a

TABLE I—INFLUENCE OF TIME OF PLANTING AND OF FERTILIZER TREATMENT UPON SIZE AND VIGOR OF PLANTS FOR TRANSPLANTING

Description of plant	I Very early			II Early			III Medium		IV Late		
	Fertilized seed bed	No fertilizer		Fertilized seed bed	No fertilizer		Fertilized seed bed	No fertilizer	Fertilized seed bed	No fertilizer	
	September 2 1924	August 25 1923	September 2 1924	September 6 1924	September 5 1923	September 6 1924	September 10 1924	September 10 1924	September 15 1924	September 15 1923	September 15 1924
Small, Poor........	0.70	7.1	0.7	2.2	3.5	1.1	6.8	6.5	8.2	11.8	5.6
Small, Medium.....	1.05	9.9	7.6	2.2	6.4	8.2	2.0	13.5	40.0	35.4	63.4
Small, Good........	0.70	2.2	22.2	0.0	3.0	15.0	2.0	12.0	8.5	12.5	2.0
Medium, Poor.......	11.60	16.2	2.8	7.9	6.4	3.9	20.4	6.5	0.3	5.9	0.0
Medium, Medium....	6.70	20.4	15.9	16.8	28.0	15.8	23.5	22.5	31.0	28.6	28.8
Medium, Good......	18.00	12.8	38.8	18.4	35.0	49.5	25.2	38.3	11.3	20.3	3.0
Large, Poor.........	6.00	3.0	0.3	2.5	0.5	0.0	3.4	0.3	0.0	0.0	0.0
Large, Medium......	9.50	11.5	4.5	13.0	4.5	1.4	7.1	0.0	0.6	0.0	0.0
Large, Good........	45.80	18.8	6.9	36.8	12.1	5.0	9.5	0.6	0.0	0.0	0.0
Total, Large........	61.3	23.3	11.7	52.3	17.1	6.4	20.0	0.9	0.6	0.0	0.0

TABLE II—INFLUENCE OF TIME OF SOWING SEED AND FERTILIZING SEED BED ON FORMATION OF SEED STALKS AND ON WINTER KILLING

Year	Treatment in seed bed	Treatment in field	Date of sowing	Per cent killed	Per cent seeders		Plants transplanted
					Based on number transplanted	Based on number living	
1923	None	Complete fertilizer	August 25	41.8	15.3	28.2	406
			September 5	22.2	14.6	26.1	404
			September 15	49.9	0.2	0.5	424
1923	None	None	August 25	38.4	16.9	27.4	373
			September 5	28.0	18.7	26.0	277
			September 15	55.7	0.7	1.6	414
1924	None	Complete fertilizer	September 2	26.6	16.4	22.4	615
			September 6	29.0	17.7	25.0	33
			September 10	45.1	4.8	8.7	672
			September 15	52.9	3.1	6.6	640
1924	Complete fertilizer plus sodium nitrate	Complete fertilizer	September 2	39.3	32.5	52.7	640
			September 6	40.4	28.0	46.8	609
			September 10	54.6	8.6	18.9	570
			September 15	57.6	3.7	8.8	618

decreased percentage of seeders. Up to and including the planting for September 6, no less than 25 per cent of the plants which survived the winter, went to seed. Sowing on September 10, only 4 days later, results in a very much lower percentage of seeders, and sowing on September 15 gives a still smaller percentage. Plots which contain high percentages of seeders, originally contained high percentages of large plants. Late planting of the seed produces small plants which do not go to seed badly, but they are quite subject to winter killing.

Influence of Fertilizer Treatment on Winter Killing and on Flower Stalk Formation

Referring again to Table II, note the effect of applying fertilizer to the plant bed in 1924. When the percentage of flower stalks formed is compared in plants from fertilized and non-fertilized areas planted on a given date, the fertilized plants are found to give the higher percentages of seeders. Generally, the differences are quite marked. Recall what was stated concerning the condition and type of plant produced on the heavily fertilized plots. It is seen that the large plants go to seed regardless of the factor responsible for the size of the plant. The fertilized plants also are winter killed much worse than the non-fertilized.

Since some are of the opinion that the fertility of the soil in which the plants are transplanted has an influence on the production of seed stalks, plants from each plant bed plot in 1923 were transplanted to ridges in the field containing both fertilizer and no fertilizer. A 7–6–5 fertilizer was placed in the ridge at transplanting time at the rate of 1000 pounds per acre, and top dressings of sodium nitrate were applied in the spring. Reference to Table III shows no appreciable difference in the percentage of seeders formed.

It was believed, however, that excessive applications of certain fertilizing constituents might so modify the growth of the plant as to influence the formation of flower stalks in one way or another. Accordingly, in 1924, acid phosphate alone was applied under the ridge at the rate of 1200 pounds per acre, and muriate of potash and nitrate of soda alone were applied at the rate of about 1300 pounds per acre. Through an error, only half as much acid phosphate was applied as was intended. Table III shows that too small a number of plants were included in the test to permit any definite conclusions to be drawn. The meagre data obtained are not in agreement with those obtained in 1923 from much larger numbers of plants. No great stress can be laid upon this point now, but it is being studied on a much larger scale this year. The results secured to date do not show any consistent effect of field fertilizing upon shooting to seed.

Influence of Climatic Factors after Transplanting, upon Formation of Flower Stalk

In an attempt to determine the influence of different winter temperatures upon the formation of flower stalks, about 100 uniform, small, vigorous plants were transplanted into a cold frame on Decem-

TABLE III—INFLUENCE OF FERTILIZER TREATMENTS IN THE FIELD ON FORMATION OF FLOWER STALKS AND ON WINTER KILLING

Date sown	Treatment in seed bed	Treatment in field	Time of application in field	Per cent seeders bzsed on number of plants living	Number of plants living	Per cent winter killed
September 10, 1924	Complete fertilizer plus sodium nitrate	Excess $NaNO_3$	Fall 12–9–24	3.8	104	26.5
		Excess Acid Phos.		9.6	117	23.6
		Excess KCl		13.0	77	55.0
		Normal, complete		17.3	127	22.1
September 10, 1924	None	Excess $NaNO_3$	Fall 12–9–24	20.9	91	37.5
		Excess Acid Phos.		22.2	54	52.5
		Excess KCl		11.9	42	66.0
		Normal, complete		11.1	90	35.5
September 10, 1924	Complete fertilizer plus sodium nitrate	Excess $NaNO_3$	Spring 5–4–25	6.1	115	36.1
		Excess Acid Phos.		9.3	97	38.6
		Excess KCl		16.0	81	43.0
		Normal, complete		20.0	120	18.5
September 10, 1924	None	Excess $NaNO_3$	Spring 5–4–25	21.4	98	30.4
		Excess Acid Phos.		7.1	56	47.6
		Excess KCl		8.3	48	55.9
		Normal, complete		26.8	56	42.8
August 25, 1923	None	Complete	Fall and spring	28.2	220	41.8
		None		27.4	230	38.4
September 5, 1923	None	Complete	Fall and spring	26.1	226	22.2
		None		26.0	196	28.0
September 15, 1923	None	Complete	Fall and spring	0.5	205	49.9
		None		1.6	183	55.7

ber 20, 1923. An exactly similar lot of plants was placed adjacent to the frame in the same kind of soil, but were given no protection. Early in May, 1924, counts were made. Although the plants in the frame had made considerably more growth than those in the open there was no appreciable difference in the percentage of seeders. Seven per cent went to seed in the frame, and eight per cent in the open. Evidently the more favorable growing conditions in the frame did not alter the potentialities of the plants which they possessed at transplanting time.

On November 22, 1924, 90 plants from each plot in the plant bed were transplanted into the greenhouse to determine whether the same tendencies to seed would be shown under continuous winter growth after a short period of rest in the plant bed, as would be shown in the field after subjection to a long period of severe weather. Unfortunately, the greenhouse temperature was allowed to run too high on some sunny days, so the plants did not make the best type of development. Late in March it became necessary to remove the plants even though they had not all reached their ultimate development. They were developed far enough, however, to determine which were seeders, and a considerable number of firm heads had formed. Table IV shows that the percentage of plants which tended to go to seed in the various plots bore essentially the same relation to each other as they did in the field. The actual percentages are not greatly different from those observed in the field, and if a larger number of plants could have been used, there would probably have been closer agreement. Here again, as in the cold frame experiment of the season before, widely different winter temperatures seemed to exert no appreciable influence upon an apparently predetermined tendency toward a certain type of development.

Chemical Studies

The analyses of samples taken in 1923 are not presented in detail since they parallel very closely the figures for the samples taken in 1924 from the early and late plantings on non-fertilized area of the plant bed. A study of the figures in Table V for the plants from the non-fertilized area of the plant bed, shows that (1) the early plants had a consistently higher C/N ratio than the plants from late sown seed, and (2) the plants showing floral organs in the spring had a higher C/N ratio than those distinctly vegetative. These are exactly the conditions observed in the 1923 studies, and they suggested that the chemical composition characterizing the plant in the fall, held over the winter and that the high C/N ratio during the fall and winter was responsible for the differentiation of reproductive organs. It was believed then, that by the application of large quantities of available nitrogen in the plant bed, the composition of the early sown plants could be made to conform to that of the late sown plants, thus securing a plant of good size and yet one which had a low C/N ratio and would not go to seed.

In 1924 the heavy fertilizing with nitrate of soda did profoundly change the composition of the plants. All through the fall and winter

TABLE IV—BEHAVIOR OF FALL GROWN PLANTS IN THE GREENHOUSE

Date of sowing	Treatment in seed bed	Per cent forming flowers	Per cent forming flower stalks	Per cent forming heads	Per cent reproductive	Per cent reproductive in the field
9-2-24	Fertilized	8.1	47.7	10.5	55.8	52.7
	None	0.0	19.5	46.5	19.5	22.4
9-6-24	Fertilized	9.9	16.0	35.8	24.9	46.8
	None	0.0	21.0	44.8	21.0	25.0
9-10-24	Fertilized	0.0	16.5	49.4	16.5	18.9
	None	0.0	12.5	40.9	12.5	8.7
9-15-24	Fertilized	0.0	12.3	40.9	12.5	8.8
	None					6.6

and even up until the early part of March, the large, early sown fertilized plants showed practically the same chemical composition as the late sown unfertilized plants. The early, fertilized plants had a much lower C/N ratio than the unfertilized plants sown at the same time. This was just the condition sought, insofar as chemical composition is concerned. The aim was achieved with a degree of success which surpassed expectations. But a rather rapid and great change occurred in the large early-sown fertilized plants which caused them to go to seed more than any other lot. In March they had a lower C/N ratio than the nonfertilized plants sown the same date. But the April samples showed the relation to be reversed.

What then is the factor in the fall and winter that can be consistently correlated with the tendency to shoot to seed? As stated above, the size of the plant in the fall seems to be invariably correlated with the tendency to form flower stalks, regardless of the C/N ratio which the plant possesses all through its fall development and winter dormancy. Still, by early April, we find that the tendency to form seed stalks is correlated with a high C/N ratio. Is it the greater size and capacity for carbohydrate synthesis in the early spring when nitrogen intake is certain to be slow, that is responsible for the radical change in the C/N ratio and the flower stalk formation in the large plants? Experiments are now in progress which it is hoped will answer this question.

It is of interest incidentally to note the changes in composition of the plants with the advent of cold weather; and later, with the return of warm weather in the spring. The almost universal phenomenon of starch hydrolysis and attainment of high sugar content is observed. Also the increase in the proportion of soluble nitrogen to total nitrogen, in the winter, is in agreement with Harvey's findings in hardy as compared with non-hardy plants.

It was also conceived that the phosphorus contained in the fertilizer used on the plant bed in 1924 might have been a factor in determining the reproductive tendency. The effect of phosphorus is generally believed to be conducive to the reproductive state and opposed to the vegetative state. The total phosphorus content was determined by the Neumann-Pemberton method, and the P/N ratios calculated as shown in Table V. The P/N ratios during the fall and winter ran parallel to the C/N ratios and the statements made above in regard to the correlation of the C/N ratio with the tendency to form seed stalks, applies equally well in the case of the P/N ratios. In April the seeders exhibited a higher P/N ratio than the nonseeders, but this correlation did not appear until April. Thus, no influence of the P/N ratio *per se* is evident in the early life of the plant. The factor responsible for the radical change in the large, fertilized plants is as yet undetermined, but it seems to exert a very potent influence on the plant which is not readily nullified by any treatment which has been given the plants after transplanting.

TABLE V—CHEMICAL COMPOSITION OF CABBAGE: ON THE BASIS OF PERCENTAGE OF DRY WEIGHT

Date sampled	Date sown	Treatment	Dry matter	Total sugars	Polysacch-arides	Starch	Soluble N	Total N	Total P	P/N	C/N
10-4-24	9-2	Ferti-lizer	14.52	10.51	16.36	9.67	.446	3.315	.445	.134	8.11
		None	12.55	13.23	20.37	13.02	.491	3.133	—	—	10.72
10-18-24	9-2	Fert.	11.47	13.84	12.12	4.11	.785	4.395	.486	.111	5.91
10-18-24	9-2	None	12.89	14.13	14.13	5.84	.594	3.890	.491	.126	7.26
10-18-24	9-15	None	11.98	6.81	12.66	5.60	.918	4.884	.501	.104	3.99
10-20-23	9-5	None	11.72	6.95	12.45	4.14	1.415	4.685	—	—	4.13
10-20-23	9-15	None	15.06	4.70	13.94	5.61	.848	4.428	—	—	4.20
11-8-24	9-2	Fert.	11.49	20.42	12.47	2.64	.868	3.963	.444	.112	8.30
11-8-24	9-2	None	12.80	23.44	16.40	5.36	.531	3.017	.390	.129	13.21
11-8-24	9-15	None	11.81	17.83	12.72	3.51	.733	4.093	.466	.114	7.46
12-11-24	9-2	Fert.	16.49	21.96	10.99	0.35	1.020	3.537	.477	.135	9.31
12-11-24	9-2	None	18.33	26.88	12.79	0.65	.582	2.450	.398	.163	16.19
12-11-24	9-15	None	17.20	19.93	10.76	0.43	1.126	3.917	.476	.122	7.83
12-21-23	9-5	None	17.89	26.06	13.31	2.56	.918	3.238	—	—	12.16
12-21-23	9-15	None	18.22	23.50	13.90	3.03	.728	3.468	—	—	10.82
3-7-25	9-2	Fert.	15.45	25.96	12.03	1.69	.884	3.627	.452	.125	10.47
3-7-25	9-2	None	16.67	24.30	12.56	1.49	.715	3.048	.438	.143	11.91
3-7-25	9-15	None	16.12	24.94	12.84	1.69	.755	3.464	Lost	—	10.90
4-9-25	9-2	Fert.*	14.05	24.89	12.81	2.34	.645	3.220	.384	.119	11.71
4-9-25	9-2	None†	14.90	22.16	13.42	2.54	.713	3.521	.355	.101	10.10
4-9-25	9-15	Fert.*	15.30	25.16	14.03	2.36	.552	3.066	.351	.114	12.78
4-9-25	9-15	None‡	15.14	21.07	12.29	2.27	.760	3.640	.376	.103	9.16
4-9-25	9-10	None§	10.45	13.77	12.36	2.42	1.049	4.802	.502	.104	5.44
4-9-25	9-10	None‖	10.64	14.47	13.87	2.59	.927	4.480	.528	.118	6.33
4-9-24	8-25	None§	14.55	15.77	14.42	3.80	.672	3.722	—	—	8.11
4-9-24	8-25	None‖	14.46	21.56	16.50	4.68	.548	3.108	—	—	11.86

*High per cent of seeders. †Medium per cent of seeders. ‡Very low per cent of seeders. §Non-seeders only. ‖Seeders only.

Behavior of Different Strains

As mentioned above, in 1923 Copenhagen as well as Jersey Wakefield was planted in the hope that it could be carried through the winter for comparison. It was planned to make some chemical studies of the different varieties. But Copenhagen is not wintered over here at all.

In 1924, Warren Wakefield, a strain introduced by Henderson Seed Company, was included in the tests. Within the strain it showed the same relative responses to time of planting and to fertilizing that Jersey Wakefield showed. But throughout, the percentage of seeders was lower, and the percentage of heads cut was higher than for Jersey Wakefield. Table VI shows the differences in percentage of seeders formed. The differences are not very great between the two strains, but they are based upon a large number of plants, so are believed to be significant.

TABLE VI—Strain Differences in the Tendency to Shoot to Seed

Date of sowing	Treatment in seed bed	Strain	Per cent seeders	Plants living
9-10-24	Fertilized	Warren Wakefield	13.7	518
		Jersey Wakefield	18.9	259
	None	Warren Wakefield	5.9	247
		Jersey Wakefield	8.7	369
9-15-24	Fertilized	Warren Wakefield	3.9	405
		Jersey Wakefield	8.8	262

Practical Aspects of the Problem

Our interest in the scientific and theoretical aspects of the problem must not cause us to lose sight of the great practical importance of it. The final yield, the ultimate return per plant transplanted, is the point which the grower is interested in. Of what profit is it to the grower to prevent flower stalk formation, if by so doing he increases the losses through winter killing? Does it make any difference as to which loss the grower chooses to stand? Moderate losses due to winter killing can be compensated for to a large extent by replanting with hot-bed, spring-grown plants, or spring plants from other sources. But losses from the formation of seed stalks appear so late in the spring that replants could not be ready for harvest in time to be of much value.

The "net efficiency" of the various methods of plant production and field management which have been discussed, has been calculated by dividing the total yield of cabbage per plot by the number of plants transplanted per plot. This takes into consideration, the combined losses from winter-killing and from seeding. As mentioned above, losses from winter-killing can be corrected to some extent, so the figures in Table VII may be lower than if replanting had been done. It will be noted that in both 1923 and 1924, seasons of very different weather conditions, the greatest return was obtained from

seed sown September 5 and 6 respectively, in seed beds of but medium fertility. The very low yields of 1924 are due to an unusually severe winter and a drought the latter part of May and first part of June.

TABLE VII—ULTIMATE YIELDS RESULTING FROM VARIOUS TREATMENTS AND DATES OF SOWING SEED

Date of sowing	Treatment in seed bed	Treatment in field	Average weight return per plant transplanted*
8-25-23	None	Fertilized None	0.59 pound 0.37 "
9-5-23	None	Fertilized None	1.32 " 0.36 "
9-15-23	None	Fertilized None	0.79 " 0.27 "
9-2-24	Fertilized None	Fertilized "	0.27 " 0.51 "
9-6-24	Fertilized None	Fertilized "	0.43 " 0.59 "
9-10-24	Fertilized None	Fertilized "	0.38 " 0.48 "
9-15-24	Fertilized None	Fertilized "	0.38 " 0.46 "

*Determined by dividing total plot yield by the number of plants transplanted.

SUMMARY

1. A survey of the literature yields good evidence that genetic factors play an important part in the tendency of cabbage to shoot to seed instead of forming heads.

2. If other factors are kept constant, and the time of sowing the seed is varied, the earlier the seed is sown the greater is the percentage of the surviving plants which go to seed. The extremes of the planting dates considered are August 25 to September 15.

3. If other factors are kept constant, heavy applications of nitrogenous fertilizers in the plant bed increase the percentage of seeders.

4. Plants exhibiting floral organs possess higher C/N and P/N ratios.

5. Lowering the C/N ratio of early-sown plants by heavy applications of nitrogenous fertilizers does not reduce the tendency to shoot to seed, but rather increases it.

6. Late planting reduces losses from shooting to seed, but increases the losses from winter-killing.

7. The factor thus far found most closely associated with the formation of seed stalks is the size of the plant transplanted.

8. Medium sized, vigorous plants are the most hardy.

9. Winter weather conditions to which the plants are subjected influence the losses from winter-killing greatly, but do not appear to change the potentialities for seed-stalk formation.

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The Effect of Fertilizers on the Earliness of Cabbage

By Donald Comin, *Experiment Station, Wooster, Ohio.*

THE district around Marietta, Washington County, Ohio, is the only locality in the State devoted to the production of carlot shipments of early vegetables. This is primarily an early trucking district and the bulk of its crops must be produced before home grown produce appears in the markets of the middle west. The time of this period is between the close of the southern and the opening of the northern shipping seasons. Prices drop sharply when this period is past. In order to secure high prices it is essential, therefore, that the grower in the Marietta district avail himself of all possible means in hastening maturity.

One of the most promising possibilities in hastening maturity of cabbage is an intelligent use of lime and fertilizers. With this vegetable, in the Marietta trucking district, the difference between profit and loss is largely a matter of earliness.

In 1915, a fertilizer experiment was instituted by the Ohio Experiment Station to aid the growers in solving their fertilizer problems and to add to our general fund of knowledge on the effect of fertilizers upon truck crop production. The plan of this experiment and the first eight years results on the total crop production were reported in Bulletin 377 of this Station by Gourley and Magruder.

This experiment embraces two series of 16 plots each, designated as series A, Soil Fertility, and series B, Soil Improvement. Each plot is one-fortieth acre in area. In series A (Plots 1-16) the plots, both treated and untreated, receive a cross dressing every second season of 2 tons of finely ground limestone per acre. After the cabbage is harvested, a cover crop of cowpeas is grown, followed by rye. Every third plot is a check.

In series B (Plots 21-36) the treatments were designed to show (1) the effect of various commercial fertilizers as supplements to manure (2) the effect of lime alone and in combination with these fertilizers (3) the effect of fresh straw mulch. The manure supplement plots (21-28 inclusive) receive a cover crop of rye after cabbage, with plots 22 and 29 as checks. The remaining 8 plots in the lime test (29-36 inclusive) receive a cover crop of cowpeas, with every third plot a check. Cabbage was grown in a four-year rotation of sweet corn, cucumbers, cabbage and tomatoes. Early Jersey Wakefield was the variety of cabbage used.

The yields from the early cutting period have been compared to illustrate the effect of the various treatments. This "early period" included from 1 to 3 cuttings, somewhat less than one-half of the crop of the earliest plots, depending upon the frequency of cutting and the character of the season. These deliberately selected periods which were determined by inspection of the detailed production records at each cutting, show clearly the conspicuous effects of fertilizers. No attempt is made here to deal with price for that introduces another factor.

Each of the elements used in commercial fertilizers as well as various combinations of these elements and manure, will be discussed in its relation to the earliness of the cabbage plant.

Nitrogen

The most valuable single fertilizer element in hastening maturity has been nitrogen. A total of 160 pounds of nitrate of soda per acre was applied in 2 equal applications, the first before the plants were set and the second approximately 3 weeks after the plants were set. The treatment resulted in an increase of 3.6 per cent in the yield of early maturing cabbage. When the entire 160 pounds was applied before the plants were set, this increase was 6.3 per cent. This treatment with nitrogen was again modified, and a portion (65 pounds) was applied in the form of sulfate of ammonia and the remaining portion (80 pounds) in the form of nitrate of soda, the total carrying the same amount of nitrogen as the former treatment. This resulted in an intermediary increase of 5.7 per cent. This seems to indicate that the value of nitrogen was greater in one application of 160 pounds of nitrate of soda than when applied in part as sulfate of ammonia.

The addition of 160 pounds of nitrate of soda to 400 pounds of acid phosphate produced an increase of 15.6 per cent in the yield of cabbage in this "early period," a difference of 12.2 per cent due to the nitrogen.

The use of 400 pounds of acid phsophate with 1 ton of limestone produced an increase of 1.9 per cent. The addition of 160 pounds of nitrate of soda as a supplement to the former treatment, gave a total increase of 15.9 per cent or an increase of 14.0 per cent due to nitrogen. This comparison points to nitrogen as the limiting factor.

The addition of 160 pounds of nitrate of soda to a fertilizer consisting of 16 tons of manure, 400 pounds of acid phosphate, and 1 ton of ground limestone, a combination carrying about 153 pounds of

nitrogen, or nearly what would be carried in 1,000 pounds of nitrate of soda, gave a still greater increase in yield. However, this increase due to added nitrogen was hardly significant, as the manure carried 124 pounds of nitrogen, a portion of which must have been available in this early period.

Phosphorus

After nitrogen was applied, the phosphates became beneficial. In series A 160 pounds of nitrate of soda when applied alone produced an increase of 6.3 per cent and upon the addition of 400 pounds of acid phosphate this figure was increased to 15.6 per cent. Considering the increases produced by either treatment alone, the benefits produced when the 2 were combined was over 1½ times that of the sum of the increases from each treatment. On the other hand, no significant increase was obtained from the addition of 400 pounds of acid phosphate to 16 tons of manure and 1 ton of ground limestone, alone or in combination.

It might be well to note at this point that the common practice with truck growers is to supplement manure with acid phosphate, or in some cases to apply acid phosphate alone to hasten maturity. The figures reported here seem to show this practice is of no value in hastening the maturity of cabbage.

Potash

Considering only the time of maturity, the cabbage plant did not use potassium to advantage under the conditions of this experiment. Plot 34, receiving 400 pounds of acid phosphate, 160 pounds of nitrate of soda, and 1 ton of ground limestone, and plot 9, receiving 400 pounds of acid phosphate plus 160 pounds of nitrate of soda, show clearly this fact, as no significant increase was obtained from 50 pounds of muriate of potash added to either treatment. The amount of potash used here may have been too small for definite conclusions to be drawn.

Limestone

Cabbage has a high calcium content in comparison with other vegetables, therefore lime may have a direct nutritive value, as well as performing other useful functions in the soil.

In partial substantiation of this statement, the figures show that 1 ton of ground limestone alone increases the yield of cabbage during the "early period" 5.5 per cent above the unlimed. Upon a detailed inspection of the check plot yields in series A receiving 2 tons of ground limestone biennially, the figures show that the limed checks in this series average considerably higher in their yielding power than did the checks in series B.

Applying 1 ton of ground limestone with 16 tons of manure, or with 610 pounds of a 4-10-4 fertilizer, produced no significant increase.

Manure

Manure, when applied alone, gave beneficial results on the plots in series B while no significant increase was obtained on the plots in series A. This seeming discrepency may be explained by the fact

that as series A receives 2 tons of ground limestone per acre, biennially, as a basic treatment in addition to the cover crop, this series is consistently a higher yielding series than B, and hence the increases due to treatments are correspondingly less on series A. This precludes a comparison of the plots of one series with the other.

Supplementing 610 pounds of a 4-10-4 fertilizer with 16 tons of manure induced no noticeable response in earliness. Manure did produce, however, a favorable reaction with lime, or with lime plus acid phosphate, probably due to the nitrogen it carries. When nitrogen was supplied in the treatment manure seemed to be of slight additional value. Manure showed no increase in the yield of early cabbage when applied as a supplement to acid phosphate.

Nitrogen and Phosphorus

Nitrogen and phosphorus, the combination alone or as a supplement to lime or lime and manure, showed a significant increase in each case. The least increase was obtained when these elements were added to manure and limestone, probably because of the fact that the latter treatment already carried about the maximum of nitrogen that could be utilized by the cabbage in this "early period."

Four hundred pounds of acid phosphate plus 160 pounds of nitrate of soda was as effective a treatment as was a complete fertilizer treatment (4–10–4) of 160 pounds. This was pointed out in the previous discussion of the value of potash as an element in fertilizers.

Limestone and Phosphorus

No consistent increase resulted from the use of 400 pounds of acid phosphate and 1 ton of limestone as a supplement to 16 tons of manure, neither was there any increase resulting from the use of this combination as a single treatment. The elements, calcium and phosphorus, seemed to be of slight value, singly or in combination, as a supplement to any treatments except those containing nitrogen. This again emphasizes the fact that probably nitrogen is the limiting factor in securing earliness in cabbage since calcium and phosphorus became beneficial only after the needed nitrogen had been added.

Limestone, Phosphorus, and Nitrate of Soda

A 4–10–4 fertilizer at the rate of 610 pounds per acre increased the early yield 14.5 per cent in series A and 17.4 per cent in series B. An additional application of 610 pounds to the plot in series A further increased this yield (14.5 per cent) by 60 per cent, giving a total increase of 22.7 per cent. Almost as large an increase was secured from 610 pounds of a 4–10–4 mixture applied as a supplement to 16 tons of manure (21.4 per cent). When the complete fertilizer was combined with 1 ton of ground limestone per year the increase was 13.6 per cent above the lime alone.

The same general magnitude of increase was obtained with 610 pounds of a 4–10–4 fertilizer supplemented by 16 tons of manure as when 1220 pounds of the same complete fertilizer was used. This

occurred despite the fact that the former treatment contained approximately 89 pounds more nitrogen, the same amount of phosphoric acid, and 104 pounds more potash. The relative availability of the nitrogen in the 2 treatments would seem to partially explain this difference.

Straw Mulch

Fresh straw mulch at the rate of 5.6 tons per acre was applied soon after the plants were set. No other treatment was given to this plot. The effect of the straw seemed to be that of retarding the growth of the young cabbage plants. The decrease (2.4 per cent) in the yield of early cabbage under that of the check plot may have been due to a depression of nitrification caused by the straw mulch.

Discussions and Conclusions

It is evident that cabbage may be brought to early maturity by the use of chemical fertilizers, ground limestone, and cover crops. In the manure more than twice as much nitrogen and potash and about half as much phosphoric acid was supplied than in the largest chemical treatment. In spite of this fact the yield was nearly equal in many cases.

It should be noted, however, that the amount of the various elements used in these treatments are not as high as are generally used by the practical truck gardener. No doubt the earnings on many such farms would justify a greater expenditure for fertilizers than has been involved in this test.

The fact that crops respond differently to fertilizer treatments should be kept in mind when determining the proper treatments to be used. Often the factors of "earliness" and of "total yield" are at variance in respect to the same treatment, and the fertilizer must be chosen with this in mind.

Summary

Under the conditions of this experiment the data may be summarized as follows:

1. The most valuable single fertilizer element used to hasten the maturity of the cabbage was nitrogen, either in the organic or inorganic form.

2. Only after nitrogen had been supplied did phosphorus seem to become beneficial. (Apparently nitrogen was the limiting factor when applying phosphorus).

3. Potash showed no significant value in hastening the maturity of cabbage. The amount of potash used in this experiment may have been too small from which to draw any definite conclusions.

4. Ground limestone, when applied alone at the rate of 1 ton per acre, had a beneficial effect on early maturity of cabbage. This treatment when combined with the elements, nitrogen, phosphorus and potash, gave no consistent additional increase in earliness.

5. The use of 16 tons of manure had some value in hastening the maturity of cabbage when applied alone (series B). Manure as a supplement to 400 pounds of acid phosphate and 1 ton of ground lime-

stone, or to the limestone alone, increased the yield of early cabbage considerably. After an additional treatment of a quickly available form of nitrogen (nitrate of soda) had been added, the 16 tons of manure resulted in no increase.

6. Nitrogen plus phosphorus, applied alone or as a supplement to limestone, or limestone and manure, was of value to increase the yield of early maturing cabbage.

7. Acid phosphate plus limestone showed no desirable effects, either singly or supplementing 16 tons of manure, in accelerating growth of the cabbage plants.

8. In all cases in which a complete fertilizer (4–10–4) was used, there were consistent increases in the yield of cabbage harvested in the "early period."

9. Straw mulch seemed to retard the growth of the cabbage and produce a sickly yellow appearance in the young plants. This was taken as indicating a depression of nitrification such as has been reported by other experimenters.

10. The results reported here show that a fertilizer consisting of 16 tons of manure, 1 ton of ground limestone, 400 pounds of acid phosphate and 160 pounds of nitrate of soda, returns the largest yield of early maturing cabbage under like conditions. The use of 1220 pounds of a complete fertilizer (4–10–4) produced the second largest crop followed in yield by a half application of the same treatment supplemented by 16 tons of manure.

Some Conditions Influencing the Determination of Catalase Activity in Plant Tissue

By JAMES E. KNOTT, *Cornell University, Ithaca, N. Y.*

THE estimation of the catalase activity of plant tissues is becoming more widely used by investigators as a measure of the relative metabolic activity, or physiological condition of various plant parts. Several methods have been used, notably those of Appleman (1), Crocker (2), and Heinicke (4), in researches where a study of the kinetics of the reaction has not been desired, but rather a relative basis of comparison. The horticulturist, if he is dealing with a rather large number of specimens under the different treatments of his investigation, is better able to discover the individual variation if he can sample a large number of these at the same time rather than base his conclusions on a composite from each treatment which is determined by a more refined method. Further than that, he wants a method which involves the least possible injury to the plants, in order to follow the growth changes. Since it is usually impossible to prepare very many simultaneously obtained samples if the catalase determination must be made soon after preparation, the problem arises how these samples may best be kept.

General Procedure

Disks one centimeter in diameter were cut from the leaves by means of a Ganong leaf cutter, and quickly transferred to a closely stoppered vial. An equal weight of powdered $CaCO_3$ was mixed with a gram of these disks, moistened with 2 cc. of distilled water and ground in a mortar for 2 minutes with a small pinch of pure quartz sand, thus insuring uniform maceration. This preparation was then diluted by washing into a bottle with 18 cc. of distilled water. To get larger samples to work with, a sufficient number of these were combined. With some types of tissue a dilution greater or less than 1 to 20 is desirable.

The catalase activity of the preparation was determined by withdrawing 2 cc. immediately after thoroughly shaking the bottle. The sample was placed in one arm of a dry reaction tube and into the other arm was placed 2 cc. of fresh dioxygen (=26 ccO_2) which had been previously neutralized with a slight excess of $CaCO_3$. The apparatus used was a modification of that of Heinicke (4) in which the leveling bulb was replaced by a glass tube of large diameter which could be slipped downward as the oxygen was evolved, thus keeping the reaction constantly under a pressure of 1 atmosphere. The reaction tube was shaken through an arc of 30° by an arm attached half way up the 17 cm. of glass tube between the top of the reaction tube and the movable support, a rubber tube clamped about the glass tube. This arm was operated by an eccentric wheel run by an electric motor at such a speed that the tube made approximately 240 complete swings per minute. By adjusting the rheostat a greater and lesser number of shakes, 220 to 300, were tested without any effect on the rate of the reaction as judged by the time for the production of 15 cc. of gas. As shown in Table I the faster shaking causes the two liquids to mix better at the start so that the initial rate is faster, but it slows down more rapidly later. A uniform rate of shaking with this apparatus is essential. A rate of 220 was found to be about the minimum at which the liquids will flow from one arm to the other.

The reaction tube was placed in a bath of water at 20°C. for 3 minutes before mixing took place, and remained submerged in this bath during the reaction. A very high degree of accuracy was obtained by the use of this method resulting in checks within 1 per cent.

Since the supernatant liquid in the catalase preparation is quite low in activity, there is always the possibility of error in drawing the 2 cc. sample if one has failed to mix the preparation well, or does not measure the 2 cc. quickly before the heavier material begins to settle out of the pipette. Failure to get close checks between duplicates can be largely laid to error in this operation. The reaction has been allowed to proceed beyond the evolution of the first 5 cc. used by Heinicke (4), because as will be noted in the first section of Table III, 2 preparations may apparently have the same activity as judged by the reaction rate up to that point, but it may drop off more rapidly in the case of one than with the other. With the reaction continuing beyond one-fifth of the contained oxygen, there is the possibility that

the supply of peroxide might become limiting to the reaction as suggested by Heinicke (4). The use of 3 cc. of peroxide containing an available 38 cc. of oxygen, with preparations of varying strength, indicates that for those producing 5 cc. of oxygen in 12 to 13 seconds there was a slight increase in the rate when more peroxide was used. Those taking about a minute were not influenced by the additional peroxide, while those requiring more than 120 to 150 seconds for 5 cc. were delayed by the extra peroxide. Such slow samples could seldom be carried much beyond the tenth cc. of oxygen. A limiting supply of peroxide has not been a factor in carrying the reaction till 60 per cent of the available oxygen has been released.

Effect of Keeping Catalase Preparation at Room Temperature

The catalase activity of apple leaf tissue was shown by Heinicke (4) to increase gradually up to the fourth day when kept at room temperature, while that of apple bark remained constant or increased slightly after three to five days if relatively strong, but if weaker, might decrease slightly or increase quite markedly.

In the present work a preparation of tomato catalase was kept in an incubator at a temperature of 22°C. for some days. The data presented in Table II indicate that this catalase preparation is far from stable and deteriorates rapidly. Sometime after 24 hours the activity begins to come back so that at 50 hours it is equal to that shortly after grinding. Spinach catalase, while relatively more stable than tomato, also deteriorates and passes through this recurrence of activity before the fiftieth hour. It is obvious from these data that one cannot expect to hold the preparations of tomato and spinach catalase at room temperature for determination on the next or succeeding days with any hope of accuracy. In both these cases, which have been repeated a number of times, the odor of decomposition is evident after 24 hours. Possibly then bacteria may have some part to play in the recovery of activity after a day.

A bottle of spinach preparation was protected from the development of bacteria by the addition of 1 per cent of toluene. The data in Table III show that while the catalase has deteriorated rather rapidly at 22°C., it has not shown the recovery of activity. To further demonstrate that this phenomenon is due to bacteria, a 30 cc. sample was placed in boiling water for 15 minutes. After cooling it was inoculated with a loop of a well decomposing preparation. A determination of the catalase activity was made and none was apparent even after 20 minutes shaking. Table IV shows the gradual return of activity as the bacterial growth increases. Putrifactive odors were present after 24 hours at 25°C.

It is clearly evident, therefore, that if one holds preparations of leaf tissues of spinach and tomatoes at room temperature, the activity after 2 days is due in part to bacteria, either by their secretion of catalase or by acting directly, and is not the activity of the catalase in the tissue itself.

TABLE I—EFFECT OF VARIOUS SPEEDS OF MIXING THE CATALASE PREPARATION AND THE PEROXIDE'

Number of complete swings per minute	Time in seconds per cubic centimeter of oxygen evolved														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
220	3	8	16	29	51	75	110	140	175	212	253	296	345	400	471
220	4	9	16	29	49	74	105	135	170	208	250	292	341	393	462
240	4	9	16	28	47	72	102	132	168	208	250	293	343	395	465
240	4	9	16	28	48	73	104	135	169	209	251	294	344	398	468
300	3	6	14	26	42	66	95	125	158	194	230	274	324	382	460
300	3	6	15	27	46	70	99	130	162	198	234	279	328	385	466

TABLE II—STABILITY OF CATALASE PREPARATIONS WHEN KEPT AT ROOM TEMPERATURE, 22°C. TIME IN SECONDS PER CUBIC CENTIMETER OF OXYGEN EVOLVED

Time after preparation	1	2	3	4	5	6	7	8	9	10	11	12	12	14	15
TOMATO															
Immediately	3	5	8	12	17	21	26	31	37	43	49	56	63	72	80
1 hour	4	7	12	17	22	28	34	40	48	56	65	74	85	95	108
3 hours	6	12	19	26	34	43	53	63	75	88	103	120	142	167	204
4 hours	6	13	21	31	43	55	67	82	97	112	131	150	172	198	230
5½ hours	6	13	23	34	47	60	75	90	107	125	145	167	193	220	250
26½ hours	13	26	42	58	77	97	118	141	170	198	233	272	320	375	447
50 hours	7	13	19	25	35	44	53	65	76	91	108	129	151	180	216
76 hours	7	14	24	34	45	58	73	89	107	129	153	183	218	258	310
169 hours	7	17	33	55	82	110	140	174	210	254	298	347	382	462	530
SPINACH															
Immediately	4	11	21	34	49	66	81	98	116	134	151	170	190	211	232
1½ hour	3	8	18	29	41	55	70	83	98	113	130	146	163	180	200
6½ hours	4	9	19	31	45	60	74	90	107	124	141	158	178	197	216
24 hours	19	36	55	75	97	116	137	159	183	205	227	250	275	300	328
51 hours	7	16	29	43	60	76	93	110	129	146	165	187	206	228	250
73½ hours	7	17	35	57	83	108	137	167	199	234	268	309	352	401	459
111 hours	7	17	34	56	83	108	145	175	210	247	285	329	380	430	491
132 hours	10	20	39	63	92	124	164	198	238	281	327	377	437	497	570

TABLE III—EFFECT OF ADDING ONE PER CENT OF TOLUENE TO PREPARATIONS OF SPINACH CATALASE. TIME IN SECONDS PER CUBIC CENTIMETER OF OXYGEN EVOLVED

Time after preparation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
At 22°C.															
One hour	5	10	17	25	36	49	66	83	103	123	145	165	191	213	240
Toluene added															
2½ hours	3	6	10	16	25	35	48	64	82	103	125	146	171	196	220
24½ hours	5	9	14	22	33	50	75	102	135	168	205	243	285	327	376
50 hours	5	10	16	24	37	59	90	127	170	217	270	326	410	464	555
74 hours	4	8	14	23	38	60	92	132	178	232	306	430	1200	—	—
99 hours	4	8	14	23	36	55	86	125	171	224	308	452	1490	—	—
At 10°C.															
One hour	5	10	18	28	41	57	78	100	126	150	178	205	233	263	293
Toluene added															
2½ hours	4	7	11	16	25	35	48	64	82	104	128	150	175	200	228
23 hours	3	6	10	16	26	38	56	76	97	122	145	171	198	225	257
50 hours	3	6	10	16	25	37	54	74	96	120	146	173	202	233	265
72 hours	7	11	15	23	35	55	80	108	137	170	202	237	272	312	358
In contact with ice															
10 minutes	5	8	14	22	35	46	61	78	97	116	135	156	177	201	226
¾ hour	4	7	13	21	30	43	56	72	88	106	125	144	165	185	207
Toluene added															
1 hour	3	5	9	15	24	34	56	62	79	96	114	135	156	178	201
27 hours	3	6	9	14	22	33	46	60	77	94	113	134	154	176	200
Toluene added when samples were 24 hours old															
Activity before toluene added	12	38	68	104	140	180	226	280	342	435 (9.5 cc.)	—	—	—	—	—
Run immediately upon addition of toluene	4	16	44	80	124	177	250	355	570	1020	—	—	—	—	—
Before addition of toluene	4	15	31	51	73	96	120	147	175	203	236	270	310	352	406
After addition of toluene	3	7	21	40	63	88	120	151	190	232	282	345	420	570	720

TABLE IV—EFFECT OF BACTERIA AS CAUSE OF THE REVIVAL OF CATALASE ACTIVITY OF SPINACH PREPARATION. TIME IN SECONDS PER CUBIC CENTIMETER OF OXYGEN EVOLVED

Time after inoculation of boiled spinach preparation	½ c.c.	1 cc.	1½ c.c.	2 cc.	2½ cc.	3 c.c.
Immediately		No activity after 20 minutes mixing				
					(2.15 cc.)	
26½ hours	—	337	—	1018	1440	—
46½ hours	—	142	—	632	1260	—
74½ hours	—	140	—	440	—	1040
99½ hours	28	128	—	430	—	995

TABLE V—STABILITY OF CATALASE PREPARATIONS WHEN KEPT AT COOL TEMPERATURES. TIME IN SECONDS PER CUBIC CENTIMETER OF OXYGEN EVOLVED

Time after preparation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TOMATO 4°C.															
1 minute	2	4	7	10	13	18	21	26	31	36	42	48	55	62	69
22 hours	4	7	11	14	18	23	28	33	38	43	50	58	65	74	83
46 hours	6	12	20	28	39	50	62	75	90	105	123	143	165	190	220
94 hours	8	20	32	48	67	87	110	139	170	210	—	—	—	—	—
168 hours	9	22	36	54	75	100	126	161	200	248	—	—	—	—	—
SPINACH 10°C.															
1 hour	5	12	24	38	56	75	95	117	138	161	183	207	232	257	286
2 hours	5	12	21	34	48	65	84	102	123	142	164	186	207	231	257
23 hours	6	13	25	41	61	81	103	126	148	172	197	222	249	267	307
51 hours	30	66	103	142	180	217	255	297	337	379	422	470	521	577	643
76 hours	10	20	33	51	69	88	107	127	148	170	190	270	235	259	285
99 hours	8	12	20	29	42	57	73	89	105	123	141	160	180	201	223
SPINACH 4°C.															
2 minutes	8	36	70	111	155	199	246	295	346	404	—	—	—	—	—
20 hours	10	32	63	101	143	190	242	300	365	443	—	—	—	—	—
48 hours	9	32	63	98	140	185	236	298	352	426	—	—	—	—	—
92 hours	10	35	71	113	158	208	262	326	398	485	—	—	—	—	—
171 hours	12	39	76	117	160	210	269	335	420	540	—	—	—	—	—
SPINACH 4°C.															
13 minutes	5	8	14	22	33	46	61	78	97	118	135	156	177	201	226
2½ hours	3	6	11	18	27	37	49	61	75	90	105	121	137	153	171
27 hours	3	6	11	18	27	38	50	63	77	92	108	124	141	159	176
99½ hours	3	6	12	20	31	45	62	79	96	115	135	155	176	199	222

Effect of Cool Temperatures on the Stability of Catalase Preparations

The use of temperatures below the normal room temperature suggests itself as a means of preserving catalase preparations. Table V. When placed in an ice box at approximately 10°C., spinach catalase preparations lose their activity as at 22 to 25°C., but since the growth of bacteria is slower, the recovery of power does not take place until between the 50 and 75 hours. The loss is such, however, that this method cannot be depended upon for accurate work. The second part of Table III shows that adding one per cent of toluene will prevent the bacterial growth at 10°C., and suggests that part of the decomposition at 10°C. is due to the action of bacteria because where they do not develop, the catalase activity is approximately constant for at least 50 hours.

The use of toluene seems to alter the rate of the reaction. In every instance the initial rate is much more rapid after the toluene has been added. In the case of the relatively more active preparations shown in Table III, the rate of evolution of the last 5 cubic centimeters of oxygen has not been materially influenced. The velocity during that period is lower and if we were to carry the reaction further the time curve would level out much more rapidly than if no toluene had been added. In the case of the weaker preparations shown in the last half of Table III, the change in velocity is very marked. It may be that the toluene in some way activates the catalase so that more of it reacts at the start, possibly less efficiently per given unit of catalase, so that later the catalase is limiting. Euler (3) found that toluene increased the catalase activity of yeast cells 6 fold. If, then, we wish to obtain as nearly as possible the catalase activity of the tissue as it is ground, it is best to avoid the use of a preservative.

Placing preparations directly on ice so that the temperature of the liquid is about 4°C., is another possible method of cutting down the bacterial growth and the decomposition of the catalase. The data in Table V show that after the initial lower activity immediately following maceration, the spinach preparation increases in activity and holds fairly constant for several days, so that with this material it would seem that the catalytic activity determined 24 hours after maceration when the preparation has reached a stable state, may be safely assumed to be the activity of the tissue. Similar results have been obtained in the case of celery. With tomato, however, as will be seen in Table V, the activity steadily decreases even directly on the ice. It does not show the increase in activity after standing a while that has been observed with other tissues. It may be that further work would show that there is a fairly proportionate decrease in activity in the case of the strong and weak samples of tomato. This being so, they could be kept over and all determined after approximately the same interval of standing without serious difficulty.

Granting that we have a tissue that seems stable enough to keep over, there is 1 factor that must be taken into consideration in determining its activity. It has been noticed that when preparations were

TABLE VI—"SPEEDING UP" OF THE CATALYTIC ACTIVITY OF VEGETABLE CATALASE PREPARATIONS WHEN EXPOSED TO THE AIR AFTER STORAGE FOR TWENTY-FOUR HOURS AT LOW TEMPERATURES. TIME IN SECONDS PER CUBIC CENTIMETER OF OXYGEN EVOLVED

A = Reaction tube connected to apparatus as soon as 2 cc. sample was drawn and placed therein.
B = Reaction tube containing 2 cc sample exposed to air for 8 minutes.

A	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	7	13	20	27	35	43	52	63	77	82	97	103	115	128	140
B	5	10	15	20	26	32	39	46	53	60	69	77	86	95	105
A	15	30	45	62	81	101	123	145	172	200	230	265	303	345	399
B	10	19	29	40	53	67	81	98	115	135	157	181	210	246	268
A	22	49	80	115	152	205	261	330	433	578	796	—	—	—	—
B	12	25	40	57	77	100	128	164	211	278	390	625	—	—	—

placed for 24 hours at 10°C. or below, directly after being made up, and 2 cubic centimeter samples were then drawn from the well-mixed liquid and placed in 2 reaction tubes, the one that was run first was always the slower. This indicated that the exposure of the 2 cubic centimeters of the preparation to the air for some minutes removed some inhibiting factor. The weaker the concentration of catalase, the greater is the magnitude of this "speeding up." This seems to reach its maximum after 6 to 8 minutes exposure to the air. In the experiments here reported 8 minutes were selected to ensure the maximum. A few representative figures are given in Table VI. Further experiments with the effect of gases on this phenomenon, which will be published later, indicate that this is probably due to the greater solubility at lower temperatures of the carbon dioxide liberated through the action of the enzymes still functioning in the macerated tissue.

The depth of the preparation in the bottle in relation to the surface exposed is probably a factor. Uncorking of the bottles during storage at the cool temperatures apparently does not influence this "speeding up." When the 2 cubic centimeters stand at room temperature this inhibitor disappears. The shaking of the bottle, if many samples are drawn, seems to assist in releasing the catalase from the action of this inhibitor.

To avoid error through this cause in delayed determinations, it is necessary to expose the small portions of the preparation to the air for 8 minutes to allow this "speeding up" to take place. Comparable results will then be obtained.

In view of the variance in the stability of the catalase of various tissues, which has lead Yamasaki (5) to believe catalase to be a group of enzymes with different nuclei, but a common side chain, it is rather essential that any investigator determine the keeping quality of the catalase of the particular tissue in which he is interested. It is believed that the storage for a short period at close to zero degrees centigrade, with due allowance for the subsequent "speeding up," will in general be found most satisfactory.

Summary

It is frequently desirable to keep preparations of plant tissue until the day after sampling before making catalase determinations.

At 10–20°C. and above the catalase deteriorates rapidly, and bacterial growth soon affects the catalytic activity.

Toluene will preserve the preparation from bacterial growth when used 1 in 100 parts, but influences the velocity.

Placing the bottles on ice immediately after maceration and dilution appears to be the best method of keeping over preparations of spinach and celery. Tomato catalase loses its activity slightly even when on ice for 24 hours.

Catalase preparations after standing at cool temperatures will show a "speeding up" or increase in relative activity, when small portions are exposed to the air before making the catalase determination.

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Investigations on Proper Maturity of California Deciduous Fruits for Eastern Shipment*

By F. W. ALLEN, *University of California, Berkeley, Calif.*

IN an effort to arrive at some standard meaning of the term maturity, as it relates to the harvesting of deciduous fruits for eastern shipment, California growers have defined "proper maturity" as that degree of development when picked from the tree, that the fruit will carry to market in firm condition and yet develop good texture and flavor.

While there are various well known rules for picking fruit at this "proper stage of maturity" these are all predicated on one's judgment and with the many varieties of fruit produced in California, each having its own characteristics as to handling and keeping qualities, the greatest need at present is to find a more definite measure of proper maturity than is now in general use. To have their fruits carry in good condition and still develop good quality is a very important and practical problem of California growers.

OUTLINE OF INVESTIGATIONS

Maturity being the result of various physical and chemical changes, both before and after the fruit is picked from the tree, the results of the investigations reported in this paper are based upon both field and laboratory work and also actual shipping tests. Work thus far has been confined to the plum, peach, and pear, the greater part of the time having been devoted to the different varieties of Japanese and European plums.

*Investigations begun in 1924 by the writer and continued in 1925 in cooperation with J. R. Magness, Bureau of Plant Industry, United States Department of Agriculture.

Methods

With all samples of fruit collected for laboratory testing an attempt was made to secure the same variety from the same trees in at least 3 stages of maturity; first picking from 3 to 10 days (depending upon the fruit) before any quantity of the fruit or particular variety was generally regarded as ready for shipment, the second picking when the variety was being shipped in largest quantity and the third picking from 3 to 10 days later. In addition to picking at the intervals mentioned above, 2 samples of different stages of maturity were occasionally picked on the same day.

A portion of each sample collected was immediately described and tested, while other parts were held under temperatures comparable to those existing in the bottom and in the top of refrigerator cars. At the end of 12 days, the usual time required for California fruit to reach the New York market, these samples were removed, described and analyzed in the same manner as the previous sample. Some of the data obtained are given in the attached table.

In comparison with these holding tests, certain test crates carefully selected, were placed in marked positions in refrigerator cars and sent to market in regular commercial shipments. Upon arrival these were examined and reported upon by a Federal inspector. Very closely associated with these shipping tests, the California Fruit Exchange in June, 1924, arranged a 6 car fruit maturity shipping test to Chicago and New York. The writer accompanied this shipment from Auburn, California, to Chicago, and had opportunity of taking car temperatures en route and of inspecting in considerable detail the fruit in one of these cars both at shipping point and at destination. Observations made on these shipments agree very closely with those made on the fruit held in cold storage under comparable temperature conditions.

Changes Previous to Picking

Increase in Size. Growth in fruit is a very obvious change but being influenced by such factors as size of crop, soil, moisture and cultural conditions, cannot be regarded as the most accurate index of maturity. Increase in size is most rapid late in the development period and in many instances if picking were delayed for a few days there would be a marked increase in quality and tonnage with a corresponding decrease in the cost of picking and packing. As an example, Bartlett pears started moving to market as soon as they attain a diameter of 2¼ inches do not develop the quality which they would if allowed to remain on the tree for an additional week or 10 days. Plums and peaches picked as soon as large enough to be of commercial size would in the majority of cases never become edible. Size, therefore, is highly desirable, but as measures of maturity there are other factors of greater importance.

Increase in Color. The second most noticeable change and one which in stone fruits usually occurs about the time the fruit is reaching its full size is the change of color. Color has been and doubtless

always will be, an important index of maturity. It is something immediately apparent to pickers and is generally recognized to be very closely associated with quality. Again, however, the development of the over-color being influenced by numerous factors is apt to be misleading, and some additional measure of maturity which may be correlated with color changes, particularly changes in ground color, is to be sought.

Changes in Sugar and Acid Content. As sugar content is generally known to increase with the maturity of the fruit, considerable data in this connection have been secured during the past 2 seasons. The soluble solids in the juice of all samples collected was determined by the use of the Balling hydrometer, while actual sugar and acid content of the fruit has been determined by chemical analyses. A few of the data obtained are given in Table I, columns 5, 6 and 7. Although these data do not show in all cases an increase in sugar content, there is in general a rather marked increase both in soluble solids and in actual sugar content and a decrease in acid between the early and later pickings.

Peaches show a less difference and also a smaller total amount of both sugar and acid than plums. Pears show an increase in sugar due to starch conversion but very little change in acid content.

As both actual and relative quantities of sugar and acid are regarded as being closely associated with quality, and since quality is largely dependent upon maturity, it would seem at first thought that measurements of sugar and acid content might furnish a satisfactory maturity index. In fact maturity standards for grapes and cantaloupes are now measured by the use of the Balling hydrometer. Will the same method apply to other fruits?

Study of the rather large amount of data secured necessitates the conclusion that while there is a general increase in sugar from day to day that such increase is relatively small until the fruit begins to assume considerable color and show indications of softening. After reaching this stage of maturity the development in sugar is usually more rapid but under present temperature conditions in transit the fruit is practically past condition for long distance shipment. Thus while a hydrometer test might be used as a check against shipping exceptionally immature fruit it is too indefinite as an accurate maturity measure except perhaps for fruit intended for local trade. Decrease in acid content, while quite consistent is too small to be of any significance in determining picking dates.

Softening of the flesh. Fruit for trans-continental shipment under present conditions must of necessity be picked before becoming appreciably soft, yet as stated in the beginning, unless the processes of maturity are well under way very poor quality is the result. The real problem, therefore, is, "How soft can the fruit be allowed to become and reach the market in good condition?"

In an endeavor to answer this question a pressure tester† was used

†Illustrated and described in detail in Cir. 350, U. S. D. A. "An Improved Type of Pressure Tester for the Determination of Fruit Maturity." By J. R. Magness and George F. Taylor.

the past season to record the firmness of all samples both at time of picking and after being held under car temperatures for 12 days. From 20 to 25 fruits of each lot were used as samples. With the sink removed from opposite sides or cheeks, the smoothly rounded plunger of the instrument, measuring seven-sixteenths inch in diameter in the case of plums and five-sixteenths inch in diameter in the case of peaches and pears, was forced into the flesh to a five-sixteenths inch depth. The tester is so constructed that when this uniform depth is reached electrical contact is made with a light and the pressure applied in pounds is read off directly. Reference to Table I, column 4, will show something of the results secured. Most varieties of plums and peaches softened from one-half to 1 pound each day while a survey of a dozen orchards showed Bartlett pears to soften from 2 to 3 pounds every 10 days. It is readily apparent that softening within a given variety is much more marked than is the increase in sugar content or in the hydrometer readings between the same samples. A test of this kind is thus regarded as a more accurate and practical measure of maturity than that based upon sugar content.

Changes After Harvesting

Even though such fruits as plums, peaches and pears are picked while still hard, colorless and tasteless, will they not reach high color, attain a pleasing flavor with good texture by the time they reach the eastern market? Apparently the assumption has too often been made that a refrigerator car possessed some magic force by which such changes are brought about. Just what changes may be expected between the time such fruit is placed in the crate or box in California and the time it is taken out for consumption?

Sugar and Acid Content. Columns 6 and 7 of Table I present a very fair sample of the changes found to take place in sugar and acid content. Naturally pears would be expected to increase their sugar content. Averaging all data secured and expressing the result in terms of *percentage increase*, as high as 40 per cent has been found, with 20 to 30 per cent being the more common figure. Crawford and Elberta peaches show rather inconsistent changes in sugar content while clingstone varieties such as Tuscan and Phillips show a slight increase. Although several of the more fleshy varieties of plums such as Burbank, Giant, and Hungarian, show a small gain, the majority of the varieties show no consistent sugar increase.

Decrease in acidity in plums when analysis is based upon the flesh of the fruit is much smaller than was anticipated. Plums, however, do show a marked decrease in the percentage of acid contained in the juice, the data showing the juice from the ripe fruit to contain from only 50 per cent to 10 per cent of the acid present when picked. Pears and peaches show little difference in the acidity present in the juice and in the flesh and the decrease is correspondingly small to the total amount which they contain. While, therefore, green pears may develop satisfactory sugar content and flavor, there is little additional development of sugar in peaches and plums after picking. What

flavor is developed, therefore, is more largely due to the decrease of acid in the juice and to the disappearance of the tannin than to increase in sugar.

Changes in Color and Firmness. Aside from the yellowing of the ground color, peaches and pears show little development of color after harvesting. Plums, however, with only a trace of red or blue color when picked for shipment may develop a high degree of color in transit. Likewise, exceptionally hard fruit may become so soft en route as to make it unfit for marketing through the regular channels. These changes in color and firmness are influenced primarily and directly by the temperatures to which the fruit is subjected. Columns 3 and 4 of Table I will illustrate these facts while Figure 1‡ illustrates the actual variation in temperatures existing in the average refrigerator car moving under standard refrigeration. The latter will also illustrate the time required to cool the fruit in various parts of the car to a constant temperature.

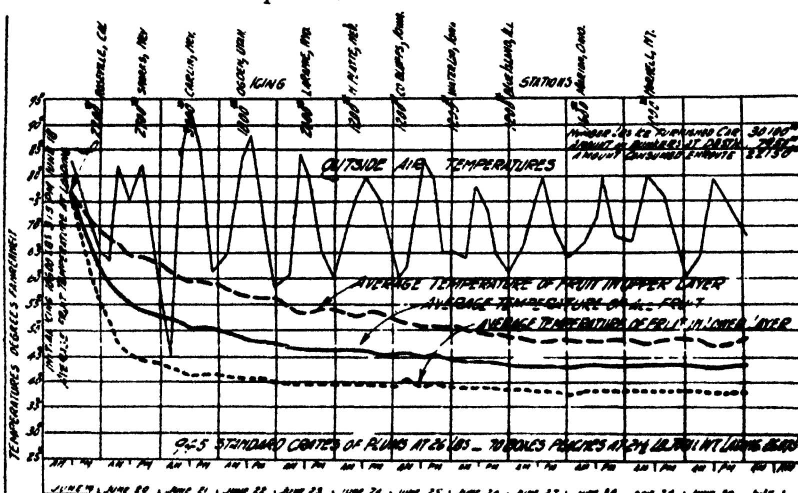

Fig. I RECORD OF TEMPERATURES IN P.F.E. 7033
PLUMS & PEACHES. LOOMIS, CAL. TO NEW YORK, N.Y.
LOADED. 10 HIGH. 5 WIDE. 2 STACKS ON STANDARD FLOOR RACKS
STANDARD REFRIGERATION

These results are very similar to those obtained by placing recording thermometers in marked crates of commercial shipments and also with test trips made by the United States Department of Agriculture. In general fruit loaded at a temperature of 75° to 80°F. in the top of a refrigerator car will carry about as follows:

1st	24 hours	70°
2nd	24 hours	60°
3rd	24 hours	56°
4th	24 hours	53°
5th	24 hours	52°
6th	24 hours	50°
7th–12th day		50°–46°

‡Courtesy of the California Fruit Exchange.

Sample number	Date picked	Color description of fruit a. when picked b. after 12 days at 43°F. c. after 12 days at 52°F.	Firmness pressure test pounds	Specific gravity of juice (Balling)	Total sugar in fruit per cent	Acidity as malic acid in juice per cent	Shipping quality	Dessert quality when ripe*
		BURBANK PLUMS						
101	June 19	a. green—straw tip	22.5	12.1	6.59	1.80	—	—
		b. light yellow	3.9	—	—	—	Good	Fair
		c. yellowish red	2.1	13.4	6.93	1.28	Good	Fair
102	June 19	a. full straw—red tip	18.9	12.9	6.89	1.77	—	—
		b. yellow—slight red	3.1	—	—	—	Good	Fair
		c. yellowish red	2.0	13.5	7.55	0.98	Good	Good
103	June 30	a. full straw—¼ red	14.0	14.5	9.05	1.22	—	—
		b. yellow—½ red	4.5	—	—	—	Good	Good
		c. full yellowish red	2.2	16.1	9.79	0.39	Good	Very good
104	July 7	a. yellow—¼ red	12.9	16.1	9.64	1.08	—	—
		b. yellow—½ red	2.9	—	—	—	Too soft	Very good
		c. deep yellow—¾ red	2.3	16.5	10.37	0.61	Too soft	Good
105	July 17	a. yellow—¼ red	10.5	16.0	10.73	0.91	—	—
		b. yellowish red	2.3	—	—	—	Too soft	Fair to good
		c. full light red	2.0	17.5	11.27	0.54	Too soft	Good

*Plums and peaches ripe upon removal from storage or within 2 days following. Pears ripe from 1 to 4 days.

Sample number	Date picked	Color description of fruit	Firmness pressure test pounds	Specific gravity of juice (Balling)	Total sugar in fruit per cent	Acidity as malic acid in juice per cent	Shipping quality	Dessert quality when ripe*
		SANTA ROSA PLUMS						
51	June 11	a. greenish yellow—red tip	17.1	11.7	6.24	2.19	—	—
		b. yellowish pink	14.1	—	—	—	Good	Poor to fair
		c. cherry red	2.7	12.3	6.21	0.70	Good	Poor to fair
52	June 11	a. ¼ to ¾ color	15.4	13.1	6.56	2.07	—	—
		b. full light red	10.8	—	—	—	Good	Fair
		c. dark red	2.6	13.1	6.61	0.53	Good	Fair to good
53	June 16	a. ¼ to ½ color	15.8	12.4	—	2.01	—	—
		b. full light red	7.4	—	—	—	Good	Good
		c. medium red	3.1	12.9	6.47	0.49	Good	Good
54	June 16	a. ¾ to full color	13.1	12.9	—	1.88	—	—
		b. full medium red	6.7	—	—	—	Good	Good
		c. dark red	3.1	14.2	7.44	0.30	Good	Very good
55	June 19	a. ¾ to full color	12.1	14.2	7.80	1.78	—	—
		b. medium red	3.1	—	—	—	Too soft	Good
		.c dark red	2.0	14.4	8.02	0.47	Too soft	Very good

		Diamond Plums						
161	July 3	a. green very faint purple	15.2	12.0	6.29	2.40	—	—
		b. ½ light purple	6.4	—	—	—	Good	Poor to fair
		c. full purple	3.5	12.2	6.35	2.15	Good	Poor to fair
162	July 3	a. ⅓ to ⅔ light purple	12.5	12.8	7.00	2.26	—	—
		b. full light purple	5.2	—	—	—	Good	Fair
		c. full dark purple	3.1	12.6	6.64	2.15	Good	Fair
163	July 9	a. ¾ to full purple	10.5	12.7	7.11	2.39	—	—
		b. full purple	2.9	—	—	—	Slightly soft	Good
		c. full dark purple	2.4	14.7	7.68	2.19	Slightly soft	Good
164	July 17	a. full light purple	8.0	15.1	8.04	1.80	—	—
		b. full purple	2.3	—	—	—	Too soft	Good—very good
		c. full purple	2.1	14.9	8.52	1.02	Too soft	Good—very good
		Early Crawford Peaches						
521	July 3	a. yellow green—very slight red	22.6	12.4	8.23	0.82	—	—
		b. cream very slight red	10.5	—	—	—	Poor—wilted	Poor, sour, wilted
		c. full yellow	11.0	11.0	8.48	0.92	Poor—wilted	Fair, slightly wilted
522	July 3	a. green-yellow to cream—good blush	19.1	12.9	8.42	0.86	—	—
		b. cream to yellow	7.6	—	—	—	Good	Fair to good
		c. mostly full yellow	7.8	12.9	8.97	0.82	Good	Fair to good
523	July 9	a. light yellow—good blush	15.0	12.4	8.14	0.88	—	—
		b. full yellow	3.4	—	—	—	Satisfactory	Fair to good
		c. full yellow to yellow red	2.1	13.6	9.24	0.79	Satisfactory	Fair

TABLE I—FRUIT MATURITY INVESTIGATIONS—(*Concluded*)

		ELBERTA PEACHES						
561	July 20	a. greenish yellow to cream—some blush	17.6	11.7	8.47	0.82	——	——
		b. greenish yellow—good blush	8.2	—	—	—	Poor—shrivelled	Poor
		c. greenish yellow—good blush	3.1	12.7	8.47	0.75	Poor—shrivelled	Fair
562	July 30	a. light yellow—slight blush	12.4	12.1	8.30	0.76	——	——
		b. light yellow—slight blush	3.5	—	—	—	Slightly soft	Fair to good
		c. yellow—¼ blush	1.7	12.8	9.09	0.67	Slightly soft	Fair to good
563	August6	a. full yellow—good blush	3.7	13.1	9.66	0.52	——	——
		b. full yellow	—	—	—	—	Poor—overripe	——
		c. full yellow	*	13.0	10.21	0.46	Poor—overripe	Excellent
		BARTLETT PEARS						
700	July 24	a. Green (size 2¼ inches)	24.5	—	5.53	—	——	——
		b. Slightly turning	23.2	—	—	—	Slightly shriv.	Poor
		c. Light yellow	4.6	12.6	7.00	0.54	Slightly shriv.	Poor
701	July 6	a. green (size 2¼–2½ inches)	22.0	11.6	5.76	0.60	——	——
		b. slightly turning	21.3	—	—	—	Good	Good
		c. light yellow	5.1	12.8	7.38	0.56	Good	Good
702	July 16	a. slightly turning (size 2½–3 inches)	19.9	11.7	6.69	0.50	——	——
		b. slightly turning	11.3	—	—	—	Good	Very good
		c. cream	4.2	12.7	7.81	0.44	Good	Very good
703	July 25	a. slightly turning (size 2½–3 inches)	19.2	12.3	7.81	0.45	——	——
		b. slightly turning	18.1	—	—	—	Good	Good
		c. light yellow	5.7	12.7	8.11	0.49	Good	Good

Temperatures in the top of the load average between 50° and 53° while average temperatures in the bottom of the load are from 10° to 15° cooler.

While no definite data have been secured on exact comparative ripening of peaches and plums, numerous observations and comparisons would indicate that ripening changes occur about twice as fast at 53°, the top of the load, as at 43°, the bottom of the load. Test shipments of comparable lots of plums show the crates loaded on the bottom of the car to have changed relatively little in transit while those on the top of the load had developed their full color and were soft. Test lots held in storage under the above temperatures showed similar differences as will be noted in column 4 of Table I.

When to Pick. With this wide range in temperature existing in refrigerator cars and its effect upon ripening of the fruit how can the problem be solved? Since it is evident that if fruit is allowed to reach that stage of maturity where it will just reach the market when loaded in the bottom of a car, the top of the load will arrive overripe. Therefore, since the grower is not at liberty to specify the most favorable location in loading and it seems impractical to load top and bottom differently, he must assume that his fruit will be subjected to the higher temperature and pick accordingly. Were it possible to hold the temperature in a refrigerator car just above the freezing point, fruit could naturally be harvested considerably riper, thus gaining in dessert quality and also possess as good if not better keeping quality after reaching prime eating condition. However, under average car temperatures shown above, the fruit must be sufficiently firm to reach the market in good condition under an average temperature of 50°F. or above, even though quality in a measure is sacrificed. In order, however, to avoid shipment of fruit so markedly immature that it will not become palatable and even of fair quality, it is believed that the pressure tester mentioned above, intelligently used in connection with color changes, will be of considerable assistance, and after another season's work it is hoped that rather definite values for firmness may be designated for the leading commercial varieties of plums, peaches and pears.

Additional Notes on Pruning and Training Grapes

By A. S. Colby,* *University of Illinois, Urbana, Ill.*

IN 1923, work was undertaken in the Experiment Station vineyard at Urbana, in an effort to determine training systems and the type and degree of severity in pruning to be recommended in growing grapes under Illinois conditions.

*A portion of the data discussed in this paper was secured through the cooperation of A. C. Vogele, formerly with the Department of Horticulture, to whom credit should be given.

TABLE I—THREE YEARS' RESULTS FROM THE TRAINING AND PRUNING OF CONCORD GRAPE VINES TO DIFFERENT SYSTEMS AND BUD NUMBERS

Bud number	16–25				26–35				36–45			
	1923	1924	1925	Three year average	1923	1924	1925	Three year average	1923	1924	1925	Three year average
Kniffin												
Average in pounds	7.94	6.17	4.6	6.24	13.44	8.00	6.62	9.35	21.42	12.37	10.02	14.60
Number of vines	51	22	5	—	57	51	35	—	54	69	74	—
Munson												
Average in pounds	—	—	—	—	12.5	12.52	8.4	11.14	14.59	15.9	12.18	14.22
Number of vines	—	—	—	—	23	21	20	—	22	32	33	—
Fan												
Average in pounds	—	—	—	—	13.19	8.06	6.0	9.08	16.41	14.47	10.0	13.63
Number of vines	—	—	—	—	26	30	12	—	37	34	18	—
Chautauqua												
Average in pounds	—	—	—	—	12.35	9.58	9.86	10.597	16.0	13.75	10.91	13.55
Number of vines	—	—	—	—	20	24	22	—	17	28	28	—

Bud number	46–55				56–65				66–75			
	1923	1924	1925	Three year average	1923	1924	1925	Three year average	1923	1924	1925	Three year average
Kniffin												
Average in pounds	24.64	15.24	13.02	17.63	27.29	19.09	15.37	20.58	—	—	—	—
Number of vines	47	54	68	—	6	39	34	—	—	—	—	—
Munson												
Average in pounds	18.69	18.27	14.294	17.085	20.82	19.23	17.97	19.34	—	—	—	—
Number of vines	24	33	34	—	25	30	32	—	—	—	—	—
Fan												
Average in pounds	17.27	16.19	10.14	14.53	22.05	17.99	12.79	17.61	—	—	—	—
Number of vines	30	31	14	—	22	24	14	—	—	—	—	—
Chautauqua												
Average in pounds	21.14	15.5	11.87	16.17	25.42	17.9	13.77	19.03	28.38	18.30	12.91	19.86
Number of vines	21	24	23	—	21	22	22	—	24	23	23	—

In addition to the conclusions arrived at after two years' work, reported briefly in the report of the Society for Horticultural Science for 1924, we have by reason of the experiments for 1925 in the same vineyard, secured additional data leading to further conclusions bearing on the same and other problems.

These studies have been carried on with over 200 Concord vines planted 10 feet square on brown silt loam of morainal type. The 4 standard systems of training, the Kniffin, Munson, Chautauqua, and Fan, were used. The accompanying table shows results of 3 seasons' work, including the average yields in pounds of grapes on vines pruned and trained to different bud numbers, using the 4 different systems of training.

It will be seen from Table I that production under the different systems of training varies slightly from year to year, there being but little difference in average production whether one system or another were used, excepting that the Fan system was, generally speaking, the lowest in production.

However, from a 3 year average, the Kniffin system appears to slightly better advantage as to average pounds production. This advantage is considerably heightened from the fact that the Kniffin system is much easier and more economical of time, labor and expense in the establishment and maintenance of the vineyard, than any of the other systems.

It is also concluded that an increase in number of buds left to the vine increases the production from that vine The Chautauqua system was the only one in which more than 65 buds were left. The increase in production in vines trained to that system was not as rapid after the 65th bud number was reached as it had been previously. The point at which this would begin to level off would be expected, of course, to vary with the conditions of growth, with such factors as initial soil fertility, organic matter and moisture playing a large part.

Since the pruning to high bud numbers decreased the amount of shoot growth the next year, it was not always possible to prune each vine to the same bud numbers consistently for the 3 years under consideration.

It was thought advisable, therefore, to study the accumulative effect of the 3 years of pruning on the 1925 crop.

TABLE II—ACCUMULATIVE EFFECT OF 1923, 1924 AND 1925 PRUNING ON 1925 CROP

Total number of buds 1923, 1924 and 1925	Number of vines	Average yield per vine 1925 in pounds
60–89 (25 per year)	26	5.36+
90–119 (35 per year)	76	10.665+
120–149 (45 per year)	66	14.38—
150–179 (55 per year)	30	15.424+

The effect of the total number of buds per vine left during the years 1923, 1924 and 1925 on the 1925 crop, shows that, when the number of buds is increased, the number of pounds per vine increases,

probably up to a certain point which we have not as yet determined. However, by the time that the number of buds left for the 3 years totals more than 120 to 149; that is, an average of 45 buds each year, the rate of increase in production is much slower as more buds are left, than before the 45 bud number per vine was reached..

Bearing on this same subject the effect of the 1925 pruning on the weight of the individual cluster of fruit shows that (Table III) as the number of buds left is increased, the weight of the individual cluster is decreased.

TABLE III—EFFECT OF NUMBER OF BUDS PER VINE ON SIZE OF CLUSTER, 1925

Range of buds	Number of vines	Number of clusters	Average weight per cluster in ounces
16–25	7	160	3.2505
26–35	36	1304	2.894
36–45	78	4456	2.769+
46–55	70	5135	2.754
56–65	46	4235	2.585

The decrease in weight of cluster compared to the increase in number of buds, is least between the 36 to 45 bud group and the 46 to 55 bud group. This decrease in weight of individual cluster is rapid after the 50 bud group is passed. Therefore, vines of Concord under conditions similar to those at this Station should in ordinary seasons be pruned to 45 to 50 buds if the greatest number of clusters of maximum size is wanted and the yield is not to be reduced.

INFLUENCE OF DIFFERENT MODIFICATIONS OF THE KNIFFIN SYSTEM OF TRAINING THE GRAPE

There has been some question in the minds of growers as to whether vines trained to the Kniffin system should be trained to a certain type of trunk such as the single, double, Y, or other modifications. Hedrick in his textbook "Manual of American Grape Growing," recommends the single trunk Kniffin system as the most productive.

Preliminary work with 2 standard Illinois varieties, Moore and Worden, using 3 possible trunk styles was undertaken in 1923 in the Station vineyard. Vines well distributed over the different sections of the vineyard were trained to the single trunk Kniffin system, the double trunk, and the Y. With the lower wire of the trellis about 30 inches from the ground, the single trunk vines were trained with no forks, and the 4 canes, especially the lower canes, arising from the trunk close to the lower wire. The vines trained to the Y trunk forked between 6 and 24 inches from the ground. The vines trained to the double trunk forked below a point 6 inches above the ground. The vines were pruned according to their characteristic growth and vigor.

Table IV shows that production from Worden vines trained to Y trunks during 1923 was slightly less than vines trained to either single or double trunks. In 1924, the difference in production was increased somewhat more, this season, however, in favor of the Y trunk. In 1925, the Y trunk was still in the lead although not so much as in

TABLE IV—EFFECT OF TYPE OF TRUNK ON PRODUCTION, WORDEN

Type of trunk	Number of vines	Average pounds per vine, 1923	Average pounds per vine, 1924	Average pounds per vine, 1925	Average in pounds 1923, 1924, 1925	Rank		
						1923	1924	1925
Single......	32	28.4± .643	18.5 ±.7704	14.3±.4468	20.4	1st	3rd	3rd
Y....	31	26.9± .8387	21.3 ±.5215	15.9±.4564	21.37	3rd	1st	1st
Double.	17	27.5±1.0619	18.82±.7449	14.7±.993	20.34	2nd	2nd	2nd

TABLE V—EFFECT OF TYPE OF TRUNK ON PRODUCTION, MOORE

Type of trunk	Number of vines	Average pounds per vine, 1923	Average pounds per vine, 1924	Average pounds per vine, 1925	Average in pounds, 1923, 1924, 1925	Rank		
						1923	1924	1925
Single.......	24	16.33+	6.73—	2.60+	8.56	2nd	3rd	1st
Y...........	38. 38, 37	16.13+	7.26	2.446	8.61+	3rd	2nd	2nd
Double......	12, 12, 11	19.67—	7.875	1.909	9.82—	1st	1st	3rd

1924. The probable error has been determined and found to be small.

Referring to Table V, showing similar figures on production of Moore we find that in 1923 and 1924 the vines trained to the double trunk lead in production by 3.33 pounds or less over the Y trunk vines, while the single trunk vines in 1925 lead by a margin of 1.5 pounds over the Y trunk vines.

From a study of the tables covering production over a period of 3 consecutive years after the vines have reached full bearing, it is concluded that vines of Worden and Moore can be trained to any one of the 3 types of trunk considered without noticeable variation in production. It is more important that a trunk be established early in the life of the vine, thus inducing early and productive bearing, than that any one particular style of trunk be chosen in the Kniffin system of training.

Importance of Organic Content of the Soil in Fertilizer and Soil Culture Experiment

By R. D. Anthony, *Pennsylvania State College, State College, Pa.*

IN Bulletin 192 of the Pennsylvania Experiment Station published early this year, certain results are given from different cultural treatments and different fertilizer applications in a 17 year old apple orchard. The past season has been abnormally dry and has served to accentuate in these experiments certain points which have gradually been growing in importance during the past 4 or 5 years.

In the fertilizer series the treatments were started in 1908 when the trees were planted and this orchard has received annual cultivation and been seeded to a nonlegume cover. Hungarian millet has been used as the cover for the past 5 years. Each block consists of 2 rows of 6 trees; of the 12 trees 4 are York Imperial, 4 Stayman Winesap and 4 Baldwin. The small number of trees has resulted in such a high degree of variability that yield and trunk circumference increase must be used cautiously as criteria in studying the results.

Until these trees were 14 years old no clear differences in fruit yields or tree growth could be detected which could be the result of the treatments. Even at that time, however, pronounced differences in cover crop growth were beginning to show, but the significance of this was not at first realized. At present, sharp differences are to be seen between certain blocks in fruit yields, trunk circumference increase, leaf color, cover crop growth and physical soil texture.

When this orchard was planted the soil, which is a limestone silt loam, had been seriously depleted by years of tenant farming until it would not grow profitable field crops. On this soil type, field crops usually make a response to applications of acid phosphate. Of the 16

plots in this experiment 6 are checks. Except for one check which is near the bottom of a slight slope, the cover crops on these checks have been poor, frequently not half as tall as on the best treated plots. The 2 plots which were originally planned to receive acid phosphate alone were changed in 1912 to complete fertilizer so this comparison was lost. Wherever acid phosphate has been combined with nitrate of soda, there has been a large response in cover crop growth.

At present when all 3 varieties are grouped, the plot having the largest yield is the check which was mentioned above as being near the bottom of a gentle slope. The second plot has received heavy applications of manure annually. Plots ranking from third through eighth have all received acid phosphate with various combinations of nitrogen and potash. Only one plot lower than the eighth has received acid phosphate. It would be a mistake to assign most of these differences to the direct effect of the fertilizer treatment; it would not have taken 14 years for direct effects to have shown with such fertilizers as nitrate of soda and acid phosphate. What has happened has been a gradual building up of the organic content of the soil in certain plots because of the response of the cover crop to the treatment, or because of favorable location in the orchard. When these results are compared on the basis of the relative amounts of organic matter returned to the soil by the treatments, or due to the location of the plot, they rank somewhat as we would expect them. In leaf color and tree growth there has been approximately the same response as in yield.

In an adjoining experiment in this same orchard legume and nonlegume covers are being compared. The trees have received annual cultivation and no fertilizers have been used. On this soil the legume mixture used has given considerably greater growth. In the Stayman Winesap block the yields and tree growth have been considerably larger in the legume cover crop area. In the York Imperial block the results are almost reversed, but here the contour of the land has resulted in considerable washing from a manure block and from 2 complete fertilizer blocks onto the nonlegume York Imperial block.

These results have all been secured with trees receiving annual cultivation. Adjoining one of these experiments are 2 series of plots which have been in sod since 1920. Before this one of these series was in sod from the date of planting, 1908, and the other under cultivation without cover crop. Until 1920, neither received applications of fertilizer, but a light straw mulch was placed around the sod trees. Continuous cultivation exhausted the soil to such a point that the trees were seriously checked. Continuous nonlegume sod without nitrogen fertilizer checked them nearly as seriously so that both these treatments were changed in 1920 to nonlegume sod with various amounts of nitrate of soda. The returns in sod growth, leaf color and tree growth, from ten-pound applications in the series

where cultivation had exhausted the organic supply of the soil, are about the same as those from five-pound applications in the continuous sod series.

At two different times in the history of this orchard, soil studies have been made of certain plots by Professor J. W. White and Professor F. G. Merkle of the Agronomy Department. The summer of 1913, the fifth season of the orchard, was very dry. Soil moisture analyses made at that time in the orchard management block showed a 50 per cent increase in the moisture content of the plot under grass with a light straw mulch as compared to the plot receiving continuous cultivation. While an anlaysis for organic matter was not made at that time there must have been a considerably greater amount in the sod plot. The effect of increased organic content on the physical condition of the soil and its water holding capacity was strikingly illustrated during the dry weather this summer. There was sufficient rain in early July to start the cover crop off in good shape, but August and September were so dry that in those plots where the cover crop growth has been unsatisfactory, the soil was so dried out that the new cover crop was killed. In the manure plot there was a heavy growth that was unchecked by the dry weather and in those plots where in other years there had been a good cover growth, this year's cover continued to grow though somewhat stunted. Where the cover crop died the killing was usually confined to the areas immediately over the roots and did not extend to a small space in the center of the square between the trees. Soil moisture studies made September 30 after 2 light rains had slightly broken the drought, showed a moisture content over the roots considerably lower than in the center—in some cases very close to the wilting point. In 2 of the plots studied the cover crop was making a good growth Here the moisture content over the roots was higher than in the center of the square and in both these locations it was from 4 to 5 per cent above the wilting point. These 2 plots had the highest organic content of those studied.

The fact that when the field was planted to trees it was a rundown pasture and that for this reason it has been difficult to grow cover crops on plots receiving no fertilization that were at all satisfactory, has served to accentuate the fertilizer effects. Even where the cover crops have done best the cover has been only moderately satisfactory and this is shown by the relatively low organic content. Plot 2 in the fertilizer experiment which has received acid phosphate and nitrate of soda and which ranks third in yield for all varieties of trees has only 55,488 pounds of organic matter to the acre, while the manure plot contains 112,283 pounds.

It would be impossible to explain the apparently conflicting results in these treatments except as we are able to relate them to changes in soil fertility which are the results either of the treatment through the cover crop, or of the location in the orchard. If we are correct in our belief that the differences in yield and tree growth are

due to the influence of the treatment, or the location on the nature of the soil, rather than due to a direct fertilizer response, then we are not justified in using these results as a basis for recommending fertilizer practices in other parts of the state, since the cover crop response may be quite different in other locations. The best we can say is that those practices which result in a heavy growth of cover crop, or of grass, should eventually lead to bigger trees and heavier yields. This is fortunate since it places the initiative directly upon the grower and demands of him that he study his own conditions and develop a sound practice.

As research workers it would seem wise for us to study first the response to our fertilizer treatments in cover crops and sod growth and when differences are seen here to expect ultimate differences in tree yields and growth.

Meeting of the Great Plains Section of the American Society for Horticultural Science

By C. P. Close, Secretary, A. S. H. S.

It was my pleasure to again meet with the Great Plains Section this year in North Dakota. This was really a field trip without any set program for the reading of papers. The trip began on August 24 at Fargo and ended at Mandan on August 27. It was in fact a joint tour with the North Dakota Horticultural Society

The forenoon of August 24, was spent in visiting the horticultural trial plots at the Agricultural College. Among the things of especial interest were the hardy plums, the bush form apple trees, and the tomatoes and sweet corn which originated there.

In the afternoon automobiles were provided and we visited truck and potato farms around Fargo and across the Red River at Moorhead, Minnesota. In the evening we were given a banquet by the citizens of Fargo.

The next day we went first to Valley City and then on to Jamestown for the night. Several good home orchards were visited and despite the late spring frost there was a good crop of apples. At Valley City the officers of the Northwest Nursery invited us to join the Rotary Club in a dinner. After this was over and the speeches made we drove to the nursery and saw very large amounts of fine nursery stock of fruits and ornamental shrubs and trees. These were all hardy plants for the bleak prairie sections.

From Jamestown we followed the county agent next day to a remarkable suburban flower and fruit garden, and to two splendid farm homes with fruit and vegetable gardens, wind breaks and ornamental plantings of shrubs, flowers and shade trees. It was a real satisfaction to see how well the farmstead plan had been worked out and completed. In the afternoon we drove on to Mandan.

The last day of the trip was a busy one. We first visited about a dozen landscaped homes in Bismarck, drove through the capitol grounds and then to the Pioneer Nursery where lunch was served by the nursery firm. The large blocks of hardy nursery stock of fruits and ornamentals were inspected. The growing of vegetable seeds here was extremely interesting.

The afternoon was reserved for a visit to the Federal Dry Land Plant Breeding Station at Mandan. Here were several real surprises in the way of large, delicious, hardy plums in full crop and the many groups of ornamental shrubs and trees. The various lines of work conducted here in the propagation and growing of hardy trees and shrubs for use in cold dry sections were especially interesting.

The attendance of A. S. H. S. members was lighter than usual, but members of the North Dakota Horticultural Society and local people at the various points visited, helped swell the crowd and the whole trip was a very pleasant and instructive one.

Dinner and Social Evening

Sixty-one members and friends enjoyed the dinner and social evening at the Baltimore Hotel. Two new features were introduced, namely, a lantern slide talk and a real business session.

As soon as the dinner was finished Prof. N. E. Hansen of Brookings, South Dakota, was introduced as the speaker of the evening. In the autumn of 1924 Prof. Hansen made an exploring trip into North China and Siberia in search of hardy blight resistant pears and other food plants which might be promising for the United States. He gave a most interesting and instructive account of his experiences on this trip and illustrated it with scores of beautiful lantern slides of scenes in those far-away countries.

Dr. E. C. Auchter then read a very witty bit of romance in which the names of varieties of apples and peaches were most skillfully used to bring out the story of a horticultural trip. After that the real business of the Society was discussed for a couple of hours. All points upon which action was taken are listed under "Items of Business."

Here is the Horticultural Trip

Last year, several Marylanders took a horticultural trip through various regions of the United States. The following people started: *Ben Davis*, *J. H. Hale*, *Martha*, *Mamie Ross*, *Fanny* and *Mother*. Our trip was a *Northwestern* one. After traveling for days on the *Chicago* and *Alton* Railroad we finally reached *Illinois*, and saw some of the sights. From *Illinois* we went north and visited *Kalamazoo* and *Milwaukee*. Here we had some *Beer's Smock*. We went down to the *Beach*, as if drawn by a *Magnet*, and there saw some bathing *Pippins*. Some of them had bathing suits which were not *Transparent* but *Opalescent*. *Mother* thought it was awful, and

Fanny pulled some *Maiden's Blush*. While here we had some *Delicious* free lemonade. From here we could see the famous *Iron Mountain* in the distance.

After an auto ride of a short time the *Mountain Rose* up before us. Here we met old *King David* and the *Duchess*, who being delighted to see us, refreshed us with *Vituals and Drink* consisting of *Beefsteak*, *Early Strawberries*, and *Smith's Cider*. After drinking the cider we were all shocked to see *Martha* doing the *Salome*. She was so good at it that she attracted the attention of *Admiral Dewey*. He said, "Oh *Marn*." We felt then that it was time to leave. But the *King* suggested that we stay to the evening opera (*Carman*) which we gladly did. The next morning, which was the *Fourth of July*, we started for *Niagara*. The *Fall-a-Water* had such a peaceful effect on *Jonathan* and the *Belle of Georgia* that they plighted their *Troth*. From *Niagara* we went on over to the *St. Lawrence* and here met *Bismark* and *Williams*. *Bismarck* had some *Sheep Nose*. He certainly looked like he had met his *Waterloo*. However he was a *Wealthy* old guy, *Champion* of many wars. In America he had won a *Wager* and in *Triumph* had selected a *Western Beauty* to take back with him.

By this time winter was approaching and we saw much *Snow* in *Rhode Island*. Getting *Chili* we started for Maryland, as our ears were *Akin* for the sunny south. Passing through *York* we saw the *Rays* of the Maryland sun, and hollered "*Eureka!, Eureka!*" The *Climax* of the trip was reached when upon arrival home we were served with *Golden Delicious*, *Stayman Winesap* and *Grimes* apples. This was certainly *Sweet Paradise*.

The members pronounced this social evening a most pleasant and profitable event. Wit and mirth bubbled forth from every speaker and shouts of merriment drove everything resembling dull care away.

Items of Business

Summer Meeting with International Conference on Plant Science

The Society accepted an invitation to hold a summer meeting in Ithaca, New York, in August, 1926 in connection with the international conference on Plant Science. The arrangement of details for this meeting was left to the executive committee. Dr. A. J. Heinicke will continue to act as the Society's representative.

Inter-Society Committee on Crown Gall

Dr. M. J. Dorsey was appointed to represent the Society and take whatever action necessary in assisting the inter-society committee on crown gall to carry on its investigations and work up its report.

Four Day Session in 1926

After considerable discussion it was decided to have the program cover four days in 1926. The chairman of the Program Committee was instructed to invite the American Society of Plant Physiologists and the Physiological Section of the Botanical Society of America, to hold a joint session of one-half day or a whole day with our Society. It was also provided that the invitation feature be included in our program for the Philadelphia meeting.

Titles of Papers by October First

It was voted unanimously that titles of papers should be submitted to the program committee by October 1 and an abstract not to exceed 200 words by December 1.

Annual Dues Increased

At the 1924 meeting an amendment to the Constitution increasing the annual dues was offered. This amendment came up for action at the 1925 meeting. After thorough discussion every member voted to increase the dues to $3.50 per year.

Honorarium for the Secretary

Since the duties of the office of Secretary-Treasurer have multiplied with the growth of the Society and the task of editing a 400 page report requires a very large amount of work and time, it was felt by all members present that the job was too big to ask the Secretary to continue doing gratis longer and while the Society could not pay a real salary it could well afford to vote the Secretary an honorarium. By unanimous vote (the Secretary not voting), the honararium was fixed at $250 per year. Provision was also made for the Secretary to employ stenographic help when necessary.

Committee on Horticultural Research Methods

After considerable discussion a motion was passed for the President to appoint a committee of five members to investigate the possibility of improving and perhaps unifying present methods of horticultural research and to report the results of its investigation with recommendations to the Society in 1926. This committee is listed with the other committees and officers on page 5 of this report.

Election of Officers

In making its report the nominating committee first submitted the names of E. C. Auchter and T. H. McHatton for President. A ballot was taken and E. C. Auchter receiving a majority of the votes was declared nominated for President. The committee then made its full report of candidates for the different offices and committees and the Secretary was instructed to cast the vote of the Society for the officers and committeemen listed on page 5 of this report.

Report of the Committee on Resolutions

The Committee on Resolutions recommends the following resolutions:—

1. *Resolved*, That we extend our heartiest thanks to the local committee for making the arrangements for this meeting and for other favors, all of which have contributed a large part toward the success of the meeting.

2. *Resolved*, That we express our sincere appreciation of the generosity of the Kansas City Athletic Club in providing such a comfortable and well appointed meeting place and for other favors extended the Society and its members.

3. *Resolved*, That we highly appreciate the work of our Secretary, C. P. Close. His unselfish and tireless efforts for the past year, and for his entire period of 18 years of service, have been the chief factor in the remarkable development which the Society has made.

4. *Resolved*, That we thank our program committee, and especially the chairman, Dr. E. C. Auchter, for developing and arranging the valuable program presented at this meeting.

T. J. TALBERT.
C. E. DURST,
C. L. FITCH,
Committee.

COMMITTEE ON STANDARDIZING INTERCOLLEGIATE FRUIT JUDGING

The following members were appointed by President Thompson to serve on this committee;—B. D. Drain, *Chairman*, O. G. Anderson, H. E. Knowlton, D. A. Kimball and C. D. Matthews. The committee's report is printed in this annual report.

Membership Roll for 1925

ALDERMAN, W. H.	University Farm, St. Paul, Minn.
ALLEN, F. W.	University Farm, Davis, Calif.
ANTHONY, R. D.	Experiment Station, State College, Pa.
ARGUE, C. W.	Iowa State College, Ames, Iowa.
ASAMI, Y.	Tokyo Imperial University, Komba near Tokyo, Japan
AUCHTER, E. C.	University of Maryland, College Park, Md.
AUSTIN, LLOYD	2601 Grant Street, Berkeley Calif.
BAILEY, J. S.	Agricultural College, Amherst, Mass.
BAILEY, L. H.	Ithaca, N. Y.
BAIRD, W. P.	Northern Great Plains Field Station, Mandan, N.D.
BALCH, W. B.	Agricultural College, Manhattan, Kans.
BALLARD, W. R.	University of Maryland, College Park, Md.
BALLARD, W. S.	U. S. Dept. Agr., Washington, D. C.
BARNETT, R. J.	Agricultural College, Manhattan, Kans.
BARRON, LEONARD	Garden City, N. Y.
BARSS, A. F.	University of British Columbia, Vancouver, B. C.
BATCHELOR, L. D.	Citrus Experiment Station, Riverside, Calif.
BEACH, F. H.	Ohio State University, Columbus, Ohio
BEAL, A. C.	Cornell University, Ithaca, N. Y.
BEATTIE, J. H.	U. S. Dept. Agr., Washington, D. C.
BEAUMONT, J. H.	University Farm, St. Paul, Minn.
BENNETT, J. P.	University of California, Berkeley, Calif.
BIOLETTA, F. T.	University of California, Berkeley, Calif.
BLAIR, J. C.	University of Illinois, Urbana, Ill.
BLAIR, W. S.	Experiment Station, Kentville, Nova Scotia
BLAKE, M. A.	Experiment Station, New Brunswick, N. J.
BOLES, A. P.	1662 Railway Exchange Bldg., St. Louis, Mo.
BOSWELL, V. R.	University of Maryland, College Park, Md.
BREGGER, J. T.	Lousiana, Mo.
BRIERLEY, W. G.	University Farm, St. Paul, Minn.
BROCK, W. S.	University of Illinois, Urbana, Ill.
BROWN, H. D.	Purdue University, Lafayette, Ind.
BUCK, F. E.	University of British Columbia, Vancouver, B. C.
BUNTING, T. R.	Macdonald College, Macdonald College P. O., Quebec, Canada
BURKHOLDER, C. L.	Purdue University, Lafayette, Ind.
BURRELL, B. J.	University Farm, St. Paul, Minn.
BUSHNELL, J. W.	Experiment Station, Wooster, Ohio
CALDWELL, J. S.	U. S. Dept. Agr., Washington, D. C.
CAMERON, S. H.	University of California, Berkeley, Calif.
CARPENTER, C. C.	Syracuse University, Syracuse, N. Y.
CARRICK, D. B.	Cornell University, Ithaca, N. Y.
CASTELLER, E. W.	Iowa State College, Ames, Iowa.
CHANDLER, W. H.	University of California, Berkeley, Calif.
CHITTENDEN, L. W.	N. Y. State School of Agriculture, Cobleskill, N. Y.
CLARK, C. F.	U. S. Dept. Agr., Washington, D. C.
CLARK, J. H.	Experiment Station, New Brunswick, N. J.
CLOSE, C. P.	U. S. Dept. Agr., Washington, D. C.
COCHRAN, G. W.	Oklahoma A. & M. College, Stillwater, Okla.
COE, F. M.	University of Nebraska, Lincoln, Neb.
COIT, J. E.	1880 Linda Vista Ave., Pasadena, Calif.
COLBY, A. S.	University of Illinois, Urbana, Ill.
COLE, W. R.	Agricultural College, Amherst, Mass.
COMIN, DONALD	Experiment Station, Wooster, Ohio.
CONDIT, I. J.	University of California, Berkeley, Calif.
CONNORS, C. H.	Experiment Station, New Brunswick, N. J.

Cooper, J. R.	University of Arkansas, Fayetteville, Ark.
Corbett, L. C.	U. S. Dept. Agr., Washington, D. C.
Crandall, C. S.	University of Illinois, Urbana, Ill.
Crane, H. L.	University of West Virginia, Morgantown, W. Va.
Crist, J. W.	Agricultural College, East Lansing, Mich.
Crow, J. W.	Simcoe, Ontario, Canada
Cullinan, F. P.	Purdue University, Lafayette, Ind.
Cummings, M. B.	University of Vermont, Burlington, Vt.
Daly, P. M.	Central Experimental Farm, Ottawa, Canada
Daniels, F. P.	Long Lake, Minn.
Darrow, G. M.	U. S. Dept. Agr., Washington, D. C.
Darrow, W. H.	Agricultural College, Storrs, Conn.
Davis, M. B.	Dominion Experimental Farm, Ottawa, Canada
Davis, V. H.	State Department of Agriculture, Columbus, Ohio
Dearing, Charles	Willard, N. C.
Detjen, L. R.	University of Delaware, Newark, Del.
Dickens, Albert	Agricultural College, Manhattan, Kans.
Dickson, G. H.	Vineland Station, Ontario, Canada
Diehl, H. A.	Wenalchee, Wash.
Dikeman, R. C.	School of Agriculture for Women, Ambler, Pa.
Dorner, H. B.	University of Illinois, Urbana, Ill.
Dorsey, M. J.	University of Illinois, Urbana, Ill.
Drain, B. D.	Agricultural College, Amherst, Mass.
Drinkard, Jr., A. W.	Experiment Station, Blacksburg, Va.
Dudley, F. N.	5 Manitou Ave., Poughkeepsie, N. Y.
Durst, C. E.	53 West Jackson Blvd., Chicago, Ill.
Dutton, W. C.	Agricultural College, East Lansing, Mich.
Dye, A. P.	University of West Virginia, Morgantown, W. Va.
Edmond, J. B.	Agricultural College, East Lansing, Mich.
Emmet, E. M.	Iowa State College, Ames, Iowa
Erwin, A. T.	Iowa State College, Ames, Iowa
Eustace, H. J.	Curtis Publishing Co., San Francisco, Calif.
Fagan, F. N.	Experiment Station, State College, Pa.
Farley, A. J.	Rutgers College, New Brunswick, N. J.
Farout, F. W.	Missouri Fruit Station, Mountain Grove, Mo.
Finch, Alton	Iowa State College, Ames, Iowa
Fisher, D. F.	Wenatchee, Wash.
Fisher, P. A.	Burlington, Ontario, Canada
Fitch, C. L.	Iowa State College, Ames, Iowa
Fletcher, S. W.	Pennsylvania State College, State College, Pa.
Floyd, W. L.	University of Florida, Gainesville, Fla.
French, A. P.	Agricultural College, Amherst, Mass.
French, W. F.	North High School, Worcester, Mass.
Frost, H. B.	Citrus Experiment Station, Riverside, Calif.
Gardner, J. S.	University of Kentucky, Lexington, Ky.
Gardner, M. E.	Clemson Agricultural College, Clemson College, S. C.
Gardner, V. R.	Agricultural College, East Lansing, Mich.
Geise, F. W.	University of Maryland, College Park, Md.
Gladwin, F. E.	Experiment Station, Fredonia, N. Y.
Gould, H. P.	U. S. Dept. Agr., Washington, D. C.
Gourley, J. H.	Experiment Station, Wooster, O.
Gray, G. F.	University of Delaware, Newark, Del.
Graves, G. W.	State Teachers & Junior College, Fresno, Calif.
Greene, L.	Purdue University, Lafayette, Ind.
Griffiths, David	U. S. Dept. Agr., Washington, D. C.
Haber, E. S.	Iowa State College, Ames, Iowa
Haller, M. H.	U. S. Dept. Agr., Washington, D. C.
Hansen, N. E.	Agricultural College, Brookings, S. D.

HARLEY, C. P. . . . . Box 907, Wenatchee, Wash.
HARTMAN, HENRY . . . . . . Oregon Agricultural College, Corvallis, Ore.
HARVEY, E. M. . . . . Oregon Agricultural College, Corvallis, Ore.
HARVEY, R. H. . . . . University Farm, St. Paul, Minn.
HEDRICK, U. P. . . . . Experiment Station, Geneva, N. Y.
HEINICKE, A. J. . . . . Cornell University, Ithaca, N. Y.
HELDER, A. H. . . . . Agricultural College, Manhattan, Kans.
HENDRICKSON, A. H. . . . University Farm, Davis, Calif.
HEPLER, J. R. . . . . Agricultural College, Durham, N. H.
HERRICK, R. S. . . . . State House, Des Moines, Iowa
HIGGINS, J. E. . . . . . . Los Banos College, Laguna, P. I.
HILDRETH, A. C. . . . . University Farm, St. Paul, Minn.
HOFFMANN, G. P. . . . . . . College of Agriculture, Clemson College, S. C.
HOFFMAN, I. C. . . . . Purdue University, Lafayette Ind.
HOLLAND, C. S. . . . . Ohio State University, Columbus, Ohio
HOLLISTER, S. P. . . . . Agricultural College, Storrs, Conn.
HOLMES, F. S. . . . . Experiment Station, College Park, Md.
HOLSINGER, C. V. . . . . Iowa State College, Ames, Iowa
HOOKER, JR., H. D. . . . . University of Missouri, Columbia, Mo.
HOPPERT, E. H. . . . . University of Nebraska, Lincoln, Neb.
HOSHINO, YUZO. . . . . . . The Tohoku Imperial University, Sapporo, Japan
HOWARD, W. L. . . . . . University Farm, Davis, Calif.
HOWE, G. H. . . . . Experiment Station, Geneva, New York
HOWLETT, F. S. . . . . . . Expt. Station, Wooster, O.
HUBER, H. F. . . . . Experiment Station, New Brunswick, N. J.
HUELSEN, W. A. . . . . University of Illinois, Urbana, Ill.
HUFFINGTON, J. M. . . . . State House, Annapolis, Md.
HUSMANN, F. L. . . . . . . Second and Seminary Streets, Napa, Calif.
HUSMANN, G. C. . . . . U. S. Dept. Agr., Washington, D. C.

ISBELL, C. L. . . . Alabama Polytechnic Institute, Auburn, Ala.

JAMISON, F. S. . . . . Iowa State College, Ames, Iowa
JENKINS, E. W. . . . . University of Vermont, Burlington, Vt.
JOHNSON, T. C. . . . . Virginia Truck Experiment Station, Norfolk, Va.
JOHNSTON, S. M. . . . . . . Experiment Station, South Haven, Mich.
JONES, H. A. . . . . University Farm, Davis, Calif.

KEENE, P. L. . . . . Agricultural College, Brookings, S. D.
KIMBALL, D. A. . . . . Agricultural College, Guelph, Ontario, Canada
KINMAN, C. F. . . . . 409 Native Sons Bldg., Sacramento, Calif.
KNOTT, J. E. . . . . Cornell University, Ithaca, N. Y.
KNOWLTON, H. E. . . . . . West Virginia University, Morgantown, W. Va.
KRAUS, E. J. . . . . University of Wisconsin, Madison, Wis.
KRAYBILL, H. R. . . . . Boyce Thompson Institute, Yonkers, N. Y.

LAGASSE, F. S. . . . . University of Delaware, Newark, Del.
LANTZ, H. L. . . . . Iowa State College, Ames, Iowa
LAVOIE, J. H. . . . . Department of Agriculture, Quebec, Canada
LESLIE, W. R. . . . . Experiment Station, Morden, Manitoba
LEWIS, I. P. . . . . Experiment Station, Marietta, Ohio
LINCOLN, F. B. . . . . Clarks Summit, Pa.
LOCKLIN, H. D. . . . . . . Western Washington Experiment Station, Puyallup, Wash.
LOMBARD, P. M. . . . . . . U. S. Dept. Agr., Washington, D. C.
LOMMEL, W. E. . . . . Purdue University, Lafayette, Ind.
LONG, C. L. . . . . Agricultural College, Corvallis, Ore.
LOOMIS, W. E. . . . . University of Arkansas, Fayetteville, Ark.
LUCE, W. A. . . . . Wenatchee, Wash.
LUMSDEN, DAVID . . . . U. S. Dept. Agr. Washington, D. C.

MACDANIELS, L. H. . . . . Cornell University, Ithaca, N. Y.
MACGILLIVRAY, J. H. . . . Purdue University, Layfayette, Ind.

MacLennan, A. H. . . . . . Agricultural College, Guelph, Ontario, Canada
McClintock, J. A. . . . . . Experiment Station, Knoxville, Tenn.
McCormick, A. C. . . . . . Husum, Wash.
McCue, C. A. . . . . Experiment Station, Newark, Del.
McHatton, T. H. . . . . . . State College of Agriculture, Athens, Ga.
McKay, H. M. . . . . State College of Agriculture, Athens, Ga.
Mack, W. B. . . . . Agricultural College, Amherst, Mass.
Mackintosh, R. S. . . . . . University Farm, St. Paul, Minn.
Macoun, W. T. . . . . Central Experimental Farm, Ottawa, Canada
Magruder, Roy. . . . . Experiment Station, Wooster, Ohio
Magness, J. R. . . . . . U. S. Dept. Agr., Washington, D. C.
Maney, T. J. . . . . . . Iowa State College, Ames, Iowa
Mann, A. J. . . . . . Experiment Station, Summerland, B. C.
Marble, L. M. . . . . Canton, Pa.
Markwell, E. D . Agricultural and Mechanical College, Stillwater, Okla.
Marsh, R. S. . University of Illinois, Urbana, Ill.
Marshall, R. E. . . . Agricultural College, East Lansing, Mich.
Mason, A. F. . . . . . University of New Jersey, New Brunswick, N. J.
Mathews, C. W. . . . Agricultural College, Lexington, Ky.
Matthews, C. D . . . . . State Board of Agriculture, Raleigh, N. C.
Mecartney, J. L . Cornell University, Ithaca, N. Y.
Merrill, M. C. . . U. S. Dept. Agr., Washington, D. C.
Merrill, Samuel. . . Iowa State College, Ames, Iowa
Mills, H. S . . . . Cornell University, Ithaca, N. Y.
Milward, J. G . . . . University of Wisconsin, Madison, Wis
Moore, J. G. . . . . . . University of Wisconsin, Madison, Wis.
Morris, L. S. . . . . Brigham Young University, Provo, Utah
Morris, O. M. . . . Experiment Station, Pullman, Wash.
Motz, F. A . . . . . . Virginia Polytechnic Institute, Blacksburg, Va.
Mulford, F. L . . U. S. Dept. Agr., Washington, D. C.
Murneek, A. E. . . University of Missouri, Columbia, Mo.
Musser, A. M. . . . . . College of Agriculture, Clemson College, S. C.
Myers, C. E . Experiment Station, State College, Pa.

Nichols, H. E. . Iowa State College, Ames, Iowa
Nightingale, G. F. . . University of New Jersey, New Brunswick, N. J.

Olney, A. J. . . . . . Experiment Station, Lexington, Ky.
Oskamp, Joseph. Cornell University, Ithaca, N. Y.
Overholser, E. L. University of California, Berkeley, Calif.
Overley, F. L . . . . . Agricultural College, Pullman, Wash.

Paddock, W . . Ohio State University, Columbus, Ohio
Page, E. M. University of Missouri, Columbia, Mo.
Palmer, E. F. . . . Vineland Station, Ontario, Canada
Palmer, R. C. . . . . Experiment Station, Summerland, B. C.
Parker, E. R. . . . Citrus Experiment Station, Riverside, Calif.
Partridge, N. L . . . Agricultural College, East Lansing, Mich.
Patterson, C. F. . . . Saskatoon, Saskatchewan, Canada
Pelton, W. C . . University of Tennessee Knoxville, Tenn.
Pentzer, W. J. . . . . Iowa State College, Ames Iowa
Phillips, H. A. . . . . . State Teachers College, Warrensburg, Mo.
Pickett, B. S. . . . . . . Iowa State College, Ames, Iowa
Pickett, W. F. . . . . Agricultural College, Manhattan, Kans.
Plagge, H. H. . . . . Iowa State College, Ames, Iowa
Potter, G. F. . . . . Agricultural College, Durham, N. H.
Price, H. L. . . . . Experiment Station, Blacksburg, Va.
Proebsting, E. L. . . . . . University Farm, Davis, Calif.

Quinn, J. T. . . . . University of Missouri, Columbia, Mo.

Randall, G. O. . . . . State College of Agriculture, Raleigh, N. C.
Ranker, E. R. . . . . Missouri Botanical Garden, St. Louis, Mo.
Rawl, E. H. . . . . Aiken, S. C.

REED, C. A.	U. S. Dept. Agr., Washington, D. C.
REED, H. J.	Experiment Station, Lafayette, Ind.
REES, R. W.	521 Cutler Building, Rochester, N. Y.
REHDER, ALFRED	Arnold Arboretum, Jamaica Plain, Mass.
REIMER, F. C.	Southern Oregon Branch Station, Talent, Ore.
RICHEY, H. W.	Iowa State College, Ames, Iowa
ROBB, O. J.	Vineland Station, Ontario, Canada
ROBBINS, W. W.	University Farm, Davis, Calif.
ROBERTS, R. H.	University of Wisconsin, Madison, Wis.
ROBERTSON, W. H.	Department of Agriculture, Victoria, B. C.
ROFKAR, W. F.	Experiment Station, Wooster, Ohio
ROSA, JR., J. T.	University Farm, Davis, Calif.
RUEF, J. U.	Iowa State College, Ames, Iowa
SAX, KARL	University of Maine, Orono, Me.
SAYRE, C. B.	Experiment Station, Geneva, N. Y.
SCHERMERHORN, L. C.	Experiment Station, New Brunswick, N. J.
SCHILLETTER, J. C.	Iowa State College, Ames, Iowa
SCHNECK, H. W.	Cornell University, Ithaca, N. Y.
SCHRADER, A. L.	University of Maryland, College Park, Md.
SCHUSTER, C. E.	Agricultural College, Corvallis, Ore.
SEARS, F. C.	Agricultural College, Amherst, Mass.
SEVY, H. P.	University of West Virginia, Morgantown, W. Va.
SHAW, J. K.	Agricultural College, Amherst, Mass.
SHAW, P. J.	Agricultural College, Truro, N. S.
SHIMA, Y.	Kuroishi Agricultural Experiment Station, Aomoriken, Japan
SHOEMAKER, D. N.	U. S. Dept. Agr., Washington, D. C.
SHOEMAKER, J. S.	Experiment Station, Wooster, Ohio
SLATE, G. L.	Experiment Station, Geneva, N. Y.
SMITH, JR., A. G.	Virginia Polytechnic Institute, Blacksburg, Va.
SMITH, ORA	Iowa State College, Ames, Iowa
SNYDER, ELMER	Hotel Willard, Fresno, Calif.
SNYDER, R. S.	Pennsylvania State College, State College, Pa.
STAFFORD, I. B.	Syracuse University, Syracuse, N. Y.
STARK, L. G.	University of West Virginia, Morgantown, W. Va.
STARRING, C. C.	Montana State College of Agriculture, Bozeman, Mont.
STRONG, W. J.	Vineland Station, Ontario, Canada.
STUART, WILLIAM	U. S. Dept. Agr., Washington, D. C.
SWARTWOUT, H. G.	University of Missouri, Columbia, Mo.
SWEETSER, H. P.	Cumberland Center, Maine
SWINGLE, C. F.	U. S. Dept. Agr., Washington, D. C.
TALBERT, T. J.	University of Missouri, Columbia, Mo.
TAPLEY, W. T.	Pennsylvania State College, State College, Pa.
TAWSE, W. J.	Macdonald College, Macdonald College, Quebec, Canada
TAYLOR, R. H.	3931 Eye St., Sacramento, Calif.
THAYER, PAUL	Pennsyvlania State College, State College, Pa.
THOMPSON, H. C.	Cornell University, Ithaca, N. Y.
TIEDJENS, V. A.	240 Beaver St., Waltham, Mass.
TRAUB, H. P.	University of Minnesota, St. Paul, Minn.
TUFTS, W. P.	University Farm, Davis, Calif.
TUKEY, H. B.	Experiment Station, Geneva, N. Y.
UNDERWOOD, F. O.	Cornell University, Ithaca, N. Y.
UPSHALL, W. H.	Horticultural Experiment Station, Vineland Station, Ontario, Canada
VAN METER, R. A.	Agricultural College, Amherst, Mass.
VIERHELLER, A. F.	University of Maryland, College Park, Md.

VINCENT, C. L. . . . . State College of Washington, Pullman, Wash.
VINSON, C. G. . . . . University Farm, St. Paul, Minn.
VOLZ, E. C. . . . . Iowa State College, Ames, Iowa

WALTER, JOHN . . . . University Farm, St. Paul, Minn.
WARING, J. H. . . . . University of Main, Orono, Me.
WATTS, R. L. . . . . Experiment Station, State College, Pa.
WEBBER, H. J. . . . . University of California, Berkeley, Calif.
WELLINGTON, J. W. . . . . U. S. Dept. Agr., Washington, D. C.
WELLINGTON, R. . . . . . . Experiment Station, Geneva, N. Y.
WELLS, H. M. . . . . Graham Horticultural Experiment Station, Grand Rapids, Mich.
WENTWORTH, S. W. . . . Agricultural College, Durham, N. H.
WERNER, H. O. . . . . University of Nebraska, Lincoln, Neb.
WESSELS, P. H. . . . . Cornell University, Ithaca, N. Y.
WESTOVER, K. C. . . . West Virginia University, Morgantown, W. Va.
WHITEHOUSE, W. E. University of Maryland, College Park, Md.
WHITMIRE, J. S. . . . . University of Illinois, Urbana, Ill.
WIGGIN, W. W. . . . . University of Maine, Orono, Me.
WIGGINS, C. B. . . . . University of Arkansas, Fayetteville, Ark.
WIGGINS, C. C. . . . . University of Nebraska, Lincoln, Neb.
WILCOX, A. N. . . . . University Farm, St. Paul, Minn.
WILLIAMS, L. C. . . . . Kansas Agricultural College, Manhattan, Kans.
WINKLER, A. J. . . . . University Farm, Davis, Calif.
WINTER, J. D. . . . . University Farm, St. Paul, Minn.
WOOD, M. N. . . . . 409 Native Sons Hall, Sacramento, Calif.
WOODBURY, C. G. . . . . . National Canners' Association, Washington, D. C.
WORK, PAUL. . . . . Cornell University, Ithaca, N. Y.

YEAGER, A. F. . . . . Agricultural College, Fargo, N. D.
YERGER, H. R. . . . . R. R. 3, Apollo, Pa.
YERKES, G. E. . . . . U. S. Dept. Agr., Washington, D. C.
YOUNG, W. J . . . . 203 North Elmwood St., Medina, Ohio

ZIMMERMAN, P. W. . . . . University of Maryland, College Park, Md.

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